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# RESEARCH MEMORANDUM

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## SOME RESEARCH ON THE LIFT AND STABILITY OF WING-BODY COMBINATIONS

[redacted]


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RESEARCH MEMORANDUM

# SOME RESEARCH ON THE LIFT AND STABILITY OF WING-BODY COMBINATIONS[1]

By Paul E. Purser and E. M. Fields

## SUMMARY

The present paper summarizes and correlates broadly some of the research results applicable to fin-stabilized ammunition. The discussion and correlation are intended to be comprehensive, rather than detailed, in order to show general trends over the Mach number range up to 7.0. Some discussion of wings, bodies, and wing-body interference is presented, and a list of 179 papers containing further information is included. The present paper is intended to serve more as a bibliography and source of reference material than as a direct source of design information.

## INTRODUCTION

A large part of the research conducted by the National Advisory Committee for Aeronautics on the lift and stability of body-wing combinations has been aimed primarily at the problems of airplanes and missiles. Many of the programs, however, have been broad enough to encompass configurations of interest to designers of fin-stabilized ammunition. It is the purpose of the present paper to summarize and correlate broadly some of the research information obtained by the NACA and other research organizations. The discussion and correlation are intended to be comprehensive, rather than detailed, in order to show general trends over the Mach number range up to $M = 7.0$. The paper is thus intended to serve more as a bibliography and source of reference material than as a direct source of design information.

References 1 to 69 and a bibliography listing 110 additional papers present information on the subject of wings and bodies and interference effects. The type of information to be found in each paper is indicated in table I.

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[1]The information presented herein was previously made available to the Fin-Stabilized Ammunition Committee, Picatinny Arsenal, Dover, N. J., July 20, 1955.

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Briefly discussed in the present paper are some interference effects, some effects of geometric changes in isolated wings, and some isolated body effects. A comparison between theory and experiment is presented for some complete configurations wherein the interference effects are combined with isolated wing and body effects.

## SYMBOLS

| | |
|---|---|
| $A$ | aspect ratio, $\frac{4s^2}{S_w}$ |
| $a$ | body radius, ft |
| $c$ | wing chord, ft |
| $c_r$ | wing root chord, ft |
| $\bar{c}$ | wing mean aerodynamic chord, $\frac{\int_0^s c^2 dy}{\int_0^s c\ dy}$, ft |
| $C_L$ | lift coefficient, $\frac{L}{qS_W}$ or $\frac{L}{qS_B}$ |
| $\Delta C_L$ | increment in $C_L$ |
| $C_{L_\alpha}$ | lift-curve slope per degree, $\frac{\partial C_L}{\partial \alpha}$ |
| $d$ | body diameter, ft |
| $K$ | distance from configuration center of gravity to trailing edge of basic wing, ft |
| $L$ | lift, lb |
| $L_{\alpha_B}$ | lift of isolated body due to angle of attack $\alpha$, lb |
| $L_{\alpha_W}$ | lift of isolated wing due to angle of attack $\alpha$, lb |
| $L_{\alpha_{W(B)}}$ | lift of wing in presence of body, lb |
| $L_{\alpha_{B(W)}}$ | lift of body in presence of wing, lb |

$\Delta L_{\alpha_{B(W)}}$ interference lift on body in presence of wing, lb

$\Delta L_{\alpha_{W(B)}}$ interference lift on wing in presence of body, lb

$l$ length of fuselage, ft

$l_c$ length of cylindrical part of body behind nose, ft

$l_n$ length of nose, ft

$M$ Mach number, $\frac{V}{V_c}$

$q$ dynamic pressure, $\frac{1}{2}\rho V^2$, lb/sq ft

$s$ wing semispan, ft

$S_W$ wing plan-form area, sq ft

$S_B$ body cross-sectional area, sq ft

$t$ wing maximum thickness, ft

$V$ velocity, ft/sec

$V_c$ velocity of sound, ft/sec

$x_{cp}$ when used alone, distance to wing center of pressure measured from wing leading edge or apex, ft

$\frac{x_{cp}}{l}$ configuration center of pressure measured from nose, expressed in body lengths

$\frac{\Delta x_{cp}}{d}$ body center of pressure rearward movement due to addition of cylinder, expressed in body diameters (fig. 15)

$x_{cp}-x_{cg}$ distance from configuration center of gravity to center of pressure, ft

$y$ spanwise distance, ft

$\alpha$ angle of attack, deg

$\rho$ density of air, slugs/cu ft

## DISCUSSION

### STATEMENT OF PROBLEM

In order to study the lift and stability of wing-body combinations, the complete configuration must be broken down into its component parts. Figure 1 shows such a breakdown for the lift. First, there is the isolated lift of the wing or fin $L_{\alpha_W}$ and that of the isolated body $L_{\alpha_B}$. When the wing is in the presence of a body which is at an angle of attack, the upflow around the body induces an "interference" lift $\Delta L_{\alpha_{W(B)}}$ on the wing such that the total lift on the wing (interference plus angle of attack) is $L_{\alpha_{W(B)}}$; similarly, the lift on a wing at angle of attack induces a lift $\Delta L_{\alpha_{B(W)}}$ on the body such that the total body lift is $L_{\alpha_{B(W)}}$. The total lift is then the sum of the components $L_{\alpha_{W(B)}} + L_{\alpha_{B(W)}}$.

Each component lift has its center of pressure, and the center of pressure of the total configuration is found by proper summation of the moments of the component lifts about some reference point such as the center of gravity. This center of pressure of the total configuration is rearward of the center of gravity for a stable configuration, and the greater this distance, the greater the stability for a given lift.

The remainder of this discussion considers the various component lifts and centers of pressure and shows the degree of success achieved by some investigators in using such component data to calculate the lift and stability of wing-body combinations.

### INTERFERENCE LIFT

The "interference" lift components are the interference wing lift in the presence of the body $\Delta L_{\alpha_{W(B)}}$ and the interference body lift in the presence of the wing $\Delta L_{\alpha_{B(W)}}$. Figure 2 presents values of these lift components calculated by linear theory and expressed as ratios of the total wing or body lift (that is, the lift due to both interference and angle of attack) to the isolated wing lift $L_{\alpha_W}$. The horizontal scale is the ratio of body radius to wing semispan, defined as shown in the sketch on the right. As the relative body radius is increased both lift ratios increase.

The increase in $L_{\alpha_{W(B)}}$ is due to the upwash at the surface of the body. This upwash has a value equal to twice the angle of attack at the body surface but decreases in the spanwise direction. Thus, as the body is made larger relative to the wing, a larger proportion of the wing is immersed in regions of large upflow angles and the value of $L_{\alpha_{W(B)}}/L_{\alpha_W}$ approaches 2.0 as the body radius approaches the wing semispan.

The increase in $L_{\alpha_{B(W)}}$ is due to the increase in body area on which the lifting-pressure carryover from the wing to the body can act as the relative body size is increased. Of course, the limiting values of 2.0 for $L_{\alpha_{W(B)}}/L_{\alpha_W}$ and $L_{\alpha_{B(W)}}/L_{\alpha_W}$ are in themselves meaningless, since at a relative body radius of 1.0 there is no wing and thus no value for $L_{\alpha_W}$. The optimum value of relative body radius exists when the increase in interference lift is balanced against the decrease in isolated wing lift. For rectangular wings this radius is approximately 0.4 semispan and the total lift is approximately 1.2 times the isolated wing lift, if the effects of decreased fin aspect ratio that occur as the body size is increased are not considered. For the more practical case in which aspect ratio must be considered, the optimum body radius would approach zero for the case of fins having aspect ratios of about 2 or less, where $C_{L_\alpha}$ varies almost directly with aspect ratio. For very high aspect ratios or very high Mach numbers, where $C_{L_\alpha}$ does not vary rapidly with aspect ratio, the optimum body radius might approach the value of 0.4 semispan.

See table I for papers containing additional information on wing-body interference.

## ISOLATED COMPONENTS

### Wings

Wings or fins may have an almost infinite variety of both plan-form and cross-sectional shapes. Three simple plan forms are used for illustration: the rectangular, the untapered sweptback, and the delta (or triangular) plan forms. Some effects on $C_{L_\alpha}$ of aspect ratio, cross-sectional shape, and end plates are discussed. The static stability of the complete configuration, as affected by the addition of wing chord, is discussed briefly. See table I for papers containing information on wings.

Effect of aspect ratio and plan form.- Figures 3 to 5 present plots of the variation with Mach number of the lift and center of pressure of rectangular, swept, and delta wings for aspect ratios of 1/2 to 4. The lift-curve slope is per degree, and the center-of-pressure locations are expressed as distance in fractions of the root-chord length behind the apex of the wings. The curves represent linear-theory (zero-thickness) values of $C_{L_\alpha}$ and $x_{cp}/c_r$, and the test points represent various experimental data presented to show the general level of agreement with the linear theory. Because lift curves for low aspect ratios are generally somewhat nonlinear, the experimental slopes have been taken over an angle-of-attack range of $\pm 4^\circ$. The experimental data are generally for wings having curved airfoil-section profiles and low values of thickness ratio ($t/c$ between 0.03 and 0.10). Some of the experimental data in figures 3 to 5 represent an average of a number of test points, and some of the experimental data in figure 4 are for a wing having a taper ratio of 0.6.

The most important points to be noted on the theoretical curves for all three plan forms are the peak in lift-curve slope $C_{L_\alpha}$ at Mach numbers near 1.0, the marked decrease in $C_{L_\alpha}$ as the aspect ratio is reduced at the lower speeds, the decrease in $C_{L_\alpha}$ as the Mach number is increased above 1.0, and the general rearward movement of the center of pressure at supersonic speeds as compared with subsonic speeds. For the two untapered plan forms the center of pressure tends to move forward at Mach numbers near 1.0, and decreases in aspect ratio tend to move the center of pressure forward at all Mach numbers. For the delta wings, decreases in aspect ratio tend to move the center of pressure rearward at subsonic speeds and have no effect on center of pressure at supersonic speeds.

The chief differences between experiment and linear theory are attributable to the effects of finite thickness, and the use of more exact theory would reduce the differences considerably. At transonic speeds the finite thickness acts somewhat like an increase in Mach number - in figure 3, for example, the most forward location of the center of pressure occurs at a lower Mach number than theory predicts for a thin plate; the same is true for the lift-curve slope peak. The experimental center of pressure is generally ahead of the location predicted by linear theory at supersonic speeds. Except for the region just above $M = 1.0$, the experimental lift-curve slope tends to agree fairly well with the linear-theory value.

Effect of adding chord on configuration static stability.- When the available wing or fin span is limited, as in the case of ammunition with fixed fins, there is often a natural desire to increase the wing lift and

thus the stability by increasing the wing area through increases in the wing chord. Figures 6 to 8 illustrate the effects of such wing-chord increases for the three wing plan forms considered, with the assumption that the trailing edge of the basic aspect-ratio-4 wing is at the rear of the body so that wing-chord increases move the leading edge forward. For simplicity, an imaginary body having no lift, no moment, and no interference is assumed so that only the wing lift and center-of-pressure location relative to the center of gravity affects the stability. Figure 6 shows the results of the analysis for rectangular wings. The distance between the imaginary center of gravity and wing center-of-pressure location is represented by $\left(x_{cp} - x_{cg}\right)/s$, the wing lift is represented by $S_W C_{L_\alpha}$, and the wing moment is represented by $S_W C_{L_\alpha}\left(x_{cp} - x_{cg}\right)/s$, all plotted against wing aspect ratio. Lengths and areas are all referenced to the semispan and area of the basic aspect-ratio-4 wing. Figure 6 shows that as the wing chord is increased, the moment arm decreases, the lift generally increases, and the resulting moment first increases and then decreases but peaks at different aspect ratios for different Mach numbers. At $M = 0.8$ the wing stability contribution peaks at $A \approx 1.5$ and as the Mach number is increased the optimum aspect ratio is decreased until at $M \approx 6$ it appears that $A < 1/2$ is the optimum. Figure 7 presents similar data for sweptback untapered wings and the general results are similar to those shown for rectangular wings. For delta wings (fig. 8) the results are again similar except that the optimum aspect ratio tends to be slightly higher than for the untapered wings for a given Mach number.

The specific values resulting from such an analysis will be changed for other plan forms and when wing-body interference and wing weight are taken into account. Another factor which would change the specific values is $K/s$, the distance from the configuration center of gravity to the trailing edge of the basic wing expressed in wing semispans. The curves of figures 6 to 8 are based on $K/s = 7.5$, and the optimum aspect ratio would be different for other values of $K/s$; for example, for the rectangular wing at $M = 6.4$ (fig. 6) the optimum aspect ratios would be approximately 0.3, 1.1, and 2.1 for $K/s$ values of 10, 2, and 1, respectively.

The general trends, based on the preceding simplified analysis, appear to be as follows:

(1) There seems to exist an optimum aspect ratio for any fin plan form below which the addition of area by increased chord will reduce the stability contribution of the fin, even though the added area is behind the center of gravity.

(2) This optimum aspect ratio for the untapered fins seems to be slightly lower than for the delta fins and also decreases as the Mach number increases.

(3) Changing the aspect ratio by changing the fin chord seemed to have the greatest effect on the fin stability contribution at the lower Mach numbers.

(4) At the higher Mach numbers the penalty suffered by not choosing the optimum aspect ratio appears to be reduced.

Since the original presentation of the present paper, a study was made (see ref. 1) of the effects of adding fin chord for rectangular and delta fins on a body of fineness ratio 14. In reference 1, body lift and moment and interference effects were considered, and the results are in general agreement with the trends previously mentioned except that the optimum aspect ratio tended to be slightly higher for the untapered fin compared with that for the delta fin.

Effect of airfoil section.- Some information on the effects of airfoil-section thickness distribution is shown in figures 9 to 11. The data of figure 9 show a comparison of the lift and center-of-pressure location at transonic speeds for tapered wings with NACA 0003-63 and 3-percent-thick circular-arc airfoils. The circular-arc airfoil has less lift and a more forward center-of-pressure location. Although the most obvious geometric difference between the two sections is the nose shape, the difference in aerodynamic chracteristics is principally due to the less obvious difference in trailing-edge angle. The angle included between the upper and lower surfaces at the trailing edge is about twice as large for the circular-arc airfoil.

The effects of a more extreme difference in the trailing-edge angle are shown in figure 10 for subsonic and low supersonic Mach numbers. The effects on lift are smaller at supersonic speeds than at subsonic speeds. The effects on center-of-pressure location are somewhat less than shown in figure 9, but this may be because the critical transonic Mach number range is not covered by the data of figure 10.

The data presented in figure 11 are for a high supersonic Mach number ($M = 6.86$) and show the effects of changing from a double-wedge or diamond airfoil to a single wedge. The effects on both lift and center-of-pressure location are appreciable but are reasonably well calculated by shock-expansion theory. The agreement between experiment and linear theory is best, of course, at low angles of attack.

Effect of end plates.- Wings or fins have often been equipped with end plates in order to reduce the tip losses, or increase the effective aspect ratio, and thus increase the lift-curve slope of the wing or fin. Figure 12 presents some data showing the effect of an end plate on the lift of a tapered wing swept back 20° at the quarter chord. The supersonic

theory for wings with end plates corresponds to the infinite-aspect-ratio value at and above the Mach number at which the particular end plate considered completely covers the tip Mach cone.

Although an end plate of reasonable size provides a considerable increase in $C_{L_\alpha}$, the increase is still not a large part of the potential gain at subsonic speeds. At supersonic speeds the same end plate will provide a greater percentage of the potential gain but the potential becomes smaller as Mach number is increased and it would appear not very worthwhile to consider end plates at the higher supersonic speeds.

## Bodies

It is in the field of bodies that the configurations used in basic research probably bear the least resemblance to practical fin-stabilized ammunition. Data do exist, however, on certain basic shapes and these data are roughly correlated herein. Because of the scatter involved in the various experimental data, the body-characteristics curves to be presented should be considered to be illustrative material showing general trends rather than design charts. See table I for papers containing information on bodies.

Lift of cones and cone-cylinders.- The upper part of figure 13 shows $C_L$ (based on body frontal area) at an angle of attack of $4^\circ$ plotted against Mach number for pure cones having fineness ratios from 3 to 7. The data showed a scatter of approximately 0.02 in $C_L$, and the faired line is slightly lower (about 7 percent) than the linear-theory value. The angle of attack of $4^\circ$ was chosen because of the basic nonlinearity of body lift data and because a considerable portion of the center-of-pressure data did not extend to lower angles of attack. The lower part of figure 13 shows the increment in $C_L$ at an angle of attack of $4^\circ$ due to the addition of cylinders of various fineness ratios to the cones. In a number of cases the curves in the lower part of figure 13 were obtained by subtracting the average value of the cone lift from the lift of the cone-cylinder combination, and this would account for part of the scatter of 0.03 to 0.04 in $C_L$.

For the pure cones, no consistent effects of cone fineness ratio or Mach number could be detected in the experimental data for $\alpha = 4^\circ$; at relatively high angles of attack, this would not necessarily be true. For the incremental lift due to the addition of a cylinder, the effects of fineness ratio and Mach number were more apparent. Increasing the length of the cylinder increased the lift, as might be expected. Increasing the Mach number increased the lift, except above $M \approx 5$, where the lift began to decrease somewhat.

Lift of ogives and ogive-cylinders.- Figure 14 is the ogive and ogive-cylinder counterpart of figure 13. The data cover about the same ranges of Mach number and cylinder fineness ratio and have about the same scatter in $C_L$ as noted for the cone-nose bodies.

The lift of the pure ogives is about 20 percent greater than for the pure cones and is about 15 percent greater than the linear-theory value. The incremental lift of cylinders behind ogives is slightly less than the incremental lift of cylinders behind cones shown in figure 13, and the data do not cover a sufficient Mach number range to show whether there is a drop in $\Delta C_L$ above $M \approx 5$ as was shown for the cylinders behind cones.

Center of pressure.- The upper part of figure 15 shows the center-of-pressure locations, at $\alpha = 4^\circ$, for pure cones and pure ogives. The lower part of figure 15 shows the increment in center-of-pressure location resulting from the addition of cylinders behind cones or ogives. Center of pressure is difficult to measure accurately, and there was considerable scatter in the data from which figure 15 was prepared. The data for the pure cones and pure ogives showed a satisfactorily small scatter of less than 10 percent of the length (less than 1/2 diameter) for center-of-pressure location. For the nose-cylinder combinations, the scatter was generally less than 3/4 diameter although several data points showed a considerably larger scatter. The scatter of the data effectively masked any effects of nose shape and small changes in Mach number, so that single curves are presented for rather large speed ranges and for both nose shapes. The curves shown in the lower part of figure 15 should be considered to be qualitative only.

The upper part of figure 15 shows that pure cones have more rearward center-of-pressure locations than do ogives and that neither nose fineness ratio nor Mach number has a consistent effect on the center-of-pressure location. Adding cylinders behind cones or ogives moves the center of pressure rearward; the increment increases with cylinder length and Mach number.

Rear end modification.- The following general trends have been noted for boattails and flares:

(1) Boattailing the rear of the body reduces the lift and moves the center of pressure forward.

(2) Flaring the rear of the body increases the lift and moves the center of pressure rearward. A flared rear end has successfully been used to provide static and dynamic stability in free flight at Mach numbers up to 10 (ref. 2).

(3) Increasing the length of the flare by including more of the cylinder length without changing the base diameter may reduce the stability contribution (ref. 3) by moving the center of pressure forward while increasing the lift slightly.

## CHARACTERISTICS OF COMPLETE CONFIGURATIONS

Having disposed, however roughly, of the various components of the lift and stability of body-wing combinations, the complete configuration may now be considered with particular attention paid to the general degree of success attained in calculating the characteristics of simple body-wing combinations. The general procedures used in the calculations were

(1) Use of the theories of Spreiter, Nielsen, Tucker, et al., to calculate the interference effects

(2) Use of the measured component $C_L$ and center-of-pressure values for the body and fins, or use of interpolation or extrapolation of experimental data (guided by theory), or use of fairly exact theory to calculate component values

(3) Summation of the component values and comparison with experimental results

### Lift

Figure 16 shows a comparison of calculated and experimental values of $C_{L_\alpha}$ for simple wing-body combinations. Data for unswept wings (tapered and rectangular) and delta wings are shown for subsonic (solid symbols) and supersonic speeds (open symbols). The agreement between calculation and experiment is good, with most of the points lying within 10 percent of the line of perfect correlation and there is no variation in quality of agreement with plan form or Mach number.

### Center of Pressure

Figure 17 is the center-of-pressure counterpart of figure 16 and the data cover the same plan form and Mach number range. The agreement between calculation and experiment is good, all points lying within 10 percent of the line of perfect correlation, and again no Mach number or plan-form trends are evident.

## CONCLUDING REMARKS

The present paper summarizes and correlates broadly some of the research results applicable to fin-stabilized ammunition. The discussion and correlation are intended to be comprehensive, rather than detailed, in order to show general trends over the Mach number range up to 7.0. The present paper is intended to serve more as a bibliography and source of reference material than as a direct source of design information.

The foregoing discussion represents a brief digest of a large amount of data. The summary figures presented are considered to be suitable only for trend studies or first-order calculations of lift and stability of particular wing-body combinations. Most of the comparisons of experiment with theory have been based on linear theory for simplicity; improved agreement will generally be obtained by use of more exact theories.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 6, 1955.

REFERENCES

1. English, Roland D.: An Analytical Study of the Effects of Increasing Fin Chord on the Lift and Longitudinal Stability Characteristics of Constant-Span Fin-Body Combinations of Fineness Ratio 14. NACA RM L56J16, 1956.

2. Piland, Robert O.: Performance Measurements From a Rocket-Powered Exploratory Research Missile Flown to a Mach Number of 10.4. NACA RM L54L29a, 1955.

3. Alley, D. J.: A Supersonic Body Profile Developmental Study. Rep. No. 6 - The Results of a Theoretical Study of Six Flared-Tailed Bodies of Revolution and Their Modifications. UMM-76 (USAF Contract W-33-038-ac-14222), Univ. of Michigan, Willow Run Res. Center, Jan. 1951.

4. Nielsen, Jack N., Kaattari, George E., and Drake, William C.: Comparison Between Prediction and Experiment for All-Movable Wing and Body Combinations at Supersonic Speeds - Lift, Pitching Moment, and Hinge Moment. NACA RM A52D29, 1952.

5. Lomax, Harvard, and Sluder, Loma: Chordwise and Compressibility Corrections to Slender-Wing Theory. NACA Rep. 1105, 1952. (Supersedes NACA TN 2295.)

6. Piland, Robert O.: Summary of the Theoretical Lift, Damping-in-Roll, and Center-of-Pressure Characteristics of Various Wing Plan Forms at Supersonic Speeds. NACA TN 1977, 1949.

7. Nelson, Warren H., and McDevitt, John B.: The Transonic Characteristics of 22 Rectangular, Symmetrical Wing Models of Varying Aspect Ratio and Thickness. NACA TN 3501, 1955. (Supersedes NACA RM A51A12.)

8. McLellan, Charles H., Bertram, Mitchel H., and Moore, John A.: An Investigation of Four Wings of Square Plan Form at a Mach Number of 6.86 in the Langley 11-Inch Hypersonic Tunnel. NACA RM L51D17, 1951.

9. Hall, Charles F.: Lift, Drag, and Pitching Moment of Low-Aspect-Ratio Wings at Subsonic and Supersonic Speeds. NACA RM A53A30, 1953.

10. Dunning, Robert W., and Ulmann, Edward F.: Aerodynamic Characteristics at Mach Number 4.04 of a Rectangular Wing of Aspect Ratio 1.33 Having a 6-Percent-Thick Circular-Arc Profile and a 30-Percent-Chord Full-Span Trailing-Edge Flap. NACA RM L53D03, 1953.

11. Martin, John C., Margolis, Kenneth, and Jeffreys, Isabella: Calculation of Lift and Pitching Moments Due to Angle of Attack and Steady Pitching Velocity at Supersonic Speeds for Thin Sweptback Tapered Wings with Streamwise Tips and Supersonic Leading and Trailing Edges. NACA TN 2699, 1952.

12. Stanbrook, A.: The Lift-Curve Slope and Aerodynamic Centre Position of Wings at Subsonic and Supersonic Speeds. Tech. Note No. Aero. 2328, British R.A.E., Nov. 1954.

13. Riebe, John M., and Watson, James M.: The Effect of End Plates on Swept Wings at Low Speeds. NACA TN 2229, 1950.

14. Weil, Joseph, and Goodson, Kenneth W.: Aerodynamic Characteristics of a Wing With Quarter-Chord Line Swept Back $45^{\circ}$, Aspect Ratio 4, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. Transonic-Bump Method. NACA RM L9A21, 1949.

15. Cahill, Jones F., and Gottlieb, Stanley M.: Low-Speed Aerodynamic Characteristics of a Series of Swept Wings Having NACA 65A006 Airfoil Sections (Revised). NACA RM L50F16, 1950.

16. Kemp, William B., Jr., Goodson, Kenneth W., and Booth, Robert A.: Aerodynamic Characteristics at a Mach Number of 1.38 of Four Wings of Aspect Ratio 4 Having Quarter-Chord Sweep Angles of $0^{\circ}$, $35^{\circ}$, $45^{\circ}$, and $60^{\circ}$. NACA RM L50G14, 1950.

17. Weissinger, J.: The Lift Distribution of Swept-Back Wings. NACA TM 1120, 1947.

18. Jaquet, Byron M., and Brewer, Jack D.: Low-Speed Static-Stability and Rolling Characteristics of Low-Aspect-Ratio Wings of Triangular and Modified Triangular Plan Forms. NACA RM L8L29, 1949.

19. Love, Eugene S.: Investigations at Supersonic Speeds of 22 Triangular Wings Representing Two Airfoil Sections for Each of 11 Apex Angles. NACA Rep. 1238, 1955. (Supersedes NACA RM L9D07.)

20. Dunning, Robert W., and Smith, Fred M.: Aerodynamic Characteristics of Two Delta Wings and Two Trapezoidal Wings at Mach Number 4.04. NACA RM L53D30a, 1953.

21. McLellan, Charles H.: Exploratory Wind-Tunnel Investigation of Wings and Bodies at $M = 6.9$. Jour. Aero. Sci., vol. 18, no. 10, Oct. 1951, pp. 641-648.

22. Emerson, Horace F., and Gale, Bernard M.: Aerodynamic Characteristics of Two Plane, Unswept Tapered Wings of Aspect Ratio 3 and 3-Percent Thickness From Tests on a Transonic Bump. NACA RM A52C07, 1952.

23. Dugan, Duane W.: Effects of Three Types of Blunt Trailing Edges on the Aerodynamic Characteristics of a Plane Tapered Wing of Aspect Ratio 3.1, With a 3-Percent-Thick Biconvex Section. NACA RM A52E01, 1952.

24. Watson, James M.: Effect of an End Plate on the Aerodynamic Characteristics of a 20.55° Sweptback Wing With an Aspect Ratio of 2.67 and a Taper Ratio of 0.5. Transonic-Bump Method. NACA RM L50H28a, 1950.

25. Jack, John R.: Aerodynamic Characteristics of a Slender Cone-Cylinder Body of Revolution at a Mach Number of 3.85. NACA RM E51H17, 1951.

26. Cooper, Ralph D., and Robinson, Raymond A.: An Investigation of the Aerodynamic Characteristics of a Series of Cone-Cylinder Configurations at a Mach Number of 6.86. NACA RM L51J09, 1951.

27. Dennis, David H., and Cunningham, Bernard E.: Forces and Moments on Pointed and Blunt-Nosed Bodies of Revolution at Mach Numbers From 2.75 to 5.00. NACA RM A52E22, 1952.

28. Lazzeroni, Frank A.: Investigation of a Missile Airframe With Control Surfaces Consisting of Projecting Quadrants of the Nose Cone. NACA RM A53L21, 1954.

29. Jack, John R.: Aerodynamics of Slender Bodies at Mach Number of 3.12 and Reynolds Numbers from $2 \times 10^6$ to $15 \times 10^6$. III - Boundary Layer and Force Measurements on a Slender Cone-Cylinder Body of Revolution. NACA RM E53B03, 1953.

30. Rabb, Leonard, and Messing, Wesley E.: Force Measurements on Cone-Cylinder Body of Revolution With Various Nose and Fin Configurations at Mach Number 4.0. NACA RM E53L29b, 1954.

31. Dennis, David H., and Cunningham, Bernard E.: Forces and Moments on Inclined Bodies at Mach Numbers From 3.0 to 6.3. NACA RM A54E03, 1954.

32. Ridyard, Herbert W.: The Aerodynamic Characteristics of Two Series of Lifting Bodies at Mach Number 6.86. NACA RM L54C15, 1954.

33. DeMeritte, F. J., and Darling, J. A.: Aeroballistic Research Investigation of Body-Alone Models at Mach Number 4.38 and 2.92. Memo. 10132, U. S. Naval Ord. Lab. (White Oak, Md.), May 3, 1950.

34. Darling, J. A., and DeMeritte, F. J.: Aeroballistics Research Investigation of NOTS Rockets. NAVORD Rep. 1506 (Aeroballistic Res. Rep. 3), U. S. Naval Ord. Lab. (White Oak, Md.), Dec. 6, 1950.

35. DeMeritte, F. J., and Darling, J. A.: Aeroballistic Research Investigation of NOTS Supersonic Rockets. NAVORD Rep. 1584 (Aeroballistics Res. Rep. 11), U. S. Naval Ord. Lab. (White Oak, Md.), Dec. 11, 1950.

36. Jaeger, B. F., and deLancey, L. M.: The Aerodynamic Characteristics at Mach Number 1.57 of 10-, 14-, and 18-Caliber Cylindrical Bare Bodies With Varying Head Shapes. NAVORD Rep. 1922 (NOTS 450), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Oct. 31, 1951.

37. Schmidt, L. E.: The Dynamic Properties of Pure Cones and Cone Cylinders. Memo. Rep. No. 759, Ballistic Res. Labs., Aberdeen Proving Ground, Jan. 1954.

38. Buford, W. E., and Shatunoff, S.: The Effects of Fineness Ratio and Mach Number on the Normal Force and Center of Pressure on Conical and Ogival Head Bodies. Memo. Rep. No. 760, Ballistic Res. Labs., Aberdeen Proving Ground, Feb. 1954.

39. Dorrance, W. H.: A Supersonic Body Profile Developmental Study. Rep. No. 3 - Twenty Degree Cone, Twenty Degree Cone Cylinder, Biconic and Ogive, Mach Number 1.90. Rep. No. UMM-63 (USAF Contract W-33-038-ac-14222), Aero. Res. Center, Univ. of Michigan, July 31, 1950.

40. Savin, Raymond C.: Application of the Generalized Shock-Expansion Method to Inclined Bodies of Revolution Traveling at High Supersonic Airspeeds. NACA TN 3349, 1955.

41. Edwards, S. Sherman: Experimental and Theoretical Study of Factors Influencing the Longitudinal Stability of an Air-to-Air Missile at a Mach Number of 1.4. NACA RM A51J19, 1952.

42. Ulmann, Edward F., and Dunning, Robert W.: Some Effects of Fin Plan Form on the Static Stability of Fin-Body Combinations at Mach Number 4.06. NACA RM L52D15a, 1952.

43. Robinson, Ross B.: Aerodynamic Characteristics at Supersonic Speeds of a Series of Wing-Body Combinations Having Cambered Wings With an Aspect Ratio of 3.5 and a Taper Ratio of 0.2 - Effects of Sweep Angle and Thickness Ratio on the Aerodynamic Characteristics in Pitch at $M = 2.01$. NACA RM L52E09, 1952.

44. Perkins, Edward W., and Kuehn, Donald M.: Comparison of the Experimental and Theoretical Distributions of Lift on a Slender Inclined Body of Revolution at $M = 2$. NACA TN 3715, 1956. (Supersedes NACA RM A53E01.)

45. Gapcynski, John P., and Robins, A. Warner: The Effect of Nose Radius and Shape on the Aerodynamic Characteristics of a Fuselage and a Wing-Fuselage Combination at Angles of Attack. NACA RM L53I23a, 1953.

46. Johnson, Harold S.: Wind-Tunnel Investigation at Low Speed of the Effect of Varying the Ratio of Body Diameter to Wing Span From 0.1 to 0.8 on the Aerodynamic Characteristics in Pitch of a 45° Sweptback-Wing—Body Combination. NACA RM L53J09a, 1953.

47. Robinson, Harold L.: Pressures and Associated Aerodynamic and Load Characteristics for Two Bodies of Revolution at Transonic Speeds. NACA RM L53L28a, 1954.

48. Perkins, Edward W., and Jorgensen, Leland H.: Comparison of Experimental and Theoretical Normal-Force Distributions (Including Reynolds Number Effects) on an Ogive-Cylinder Body at Mach Number 1.98. NACA TN 3716, 1956. (Supersedes NACA RM A54H23.)

49. Burrows, Dale L., and Palmer, William E.: A Transonic Wind-Tunnel Investigation of the Force and Moment Characteristics of a Plane and a Cambered 3-Percent-Thick Delta Wing of Aspect Ratio 3 on a Slender Body. NACA RM L54H25, 1954.

50. Nestingen, I. M.: Aeroballistic Research Investigation of the 0.325 Scale Model of the Surface-to-Air Missile Zeus (XSAM-N-8) at Mach Numbers of 1.57, 1.88, 2.48, and 3.25. Memo. 10100, U. S. Naval Ord. Lab. (White Oak, Md.), Aug. 19, 1949.

51. DeMeritte, Fred J.: Aeroballistic Research Investigation of a Family of Rectangular Finned Models at Mach Number 2.92. Memo. 10117, U. S. Naval Ord. Lab. (White Oak, Md.), Jan. 3, 1950.

52. DeLancey, L. M., and Jaeger, B. F.: The Aerodynamic Characteristics at Subsonic Velocities of 10-, 14-, and 18-Caliber Fin-Stabilized Rockets With Varying Body and Fin Parameters. NAVORD Rep. 1194 (NOTS 250), U. S. Naval Ord. Test Station (Inyokern, Calif.), Oct. 20, 1949.

53. Jaeger, B. F., and Brown, A. E.: The Aerodynamic Characteristics at Mach Number 2.0 of 14- and 18-Caliber Fin-Stabilized Rockets With Varying Body and Fin Parameters. NAVORD Rep. 1211 (NOTS 267), U. S. Naval Ord. Test Station (Inyokern, Calif.), Jan. 20, 1950.

54. Brown, C. S., Luther, M. L., and Schroedter, G. M.: Experimental Studies of Forces, Pressure Distributions, and Viscous Effects on Long Inclined Bodies of Revolution at Mach 2.96. U. S. Naval Ord. Test Station, Inyokern, Calif., NAVORD Rep. 1281 - NOTS 351, 1951.

55. Jaeger, B. F., deLancey, L. M., and Schroedter, G. M.: Aerodynamic Characteristics at Mach Number 2.87 of 14- and 18-Caliber Fin-Stabilized Rocket Models With Varying Fin Parameters. NAVORD Rep. 1331 (NOTS 411), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), July 24, 1951.

56. DeMeritte, Fred, Shantz, Irving, and Darling, John: Aeroballistic Investigation of the NOTS Rockets at Subsonic and Supersonic Speeds. NAVORD Rep. 1874 (Aeroballistic Res. Rep. 32), U. S. Naval Ord. Lab. (White Oak, Md.), Oct. 1, 1951.

57. Jaeger, B. F., and deLancey, L. M.: The Aerodynamic Characteristics at Mach Number 1.87 of 14- and 18-Caliber Fin-Stabilized Rocket Models With Varying Fin Parameters. NAVORD Rep. 1918 (NOTS 447), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Oct. 10, 1951.

58. Jaeger, B. F., and deLancey, L. M.: The Aerodynamic Characteristics at Mach Number 4.24 of 10-, 14-, and 18-Caliber Fin-Stabilized Rocket Models With Varying Fin Parameters. NAVORD Rep. 1950 (NOTS 504), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Mar. 19, 1952.

59. Luther, Marvin L., and Drinkwater, W. D.: The Aerodynamic Characteristics of Fin-Stabilized Rocket Models With Oversized Heads. Part 2. Mach Number 0.80. NAVORD Rep. 1972, Pt. 2 (NOTS 556), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), July 25, 1952.

60. Luther, Marvin L., and Drinkwater, W. D.: The Aerodynamic Characteristics of Fin-Stabilized Rocket Models With Oversized Heads. Part 3. Mach Number 1.86. NAVORD Rep. 1972, Pt. 3 (NOTS 593), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Oct. 17, 1952.

61. Luther, Marvin L., and Drinkwater, W. D.: The Aerodynamic Characteristics of Fin-Stabilized Rocket Models With Oversized Heads. Part 4. Mach Number 2.87. NAVORD Rep. 1972, Pt. 4 (NOTS 594), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Oct. 17, 1952.

62. Luchuk, W.: Static Stability and Drag Measurements on a 0.289-Scale Model of the Angled Arrow Projectile at a Mach Number of 4.28 Using Various Nose and Fin Configurations. NAVORD Rep. 2853 (Aeroballistic Res. Rep. 174), U. S. Naval Ord. Lab. (White Oak, Md.), Apr. 29, 1953.

63. Thomas, Nancy: Aberdeen Wind-Tunnel Test Results (M = 1.28 - 3.77) of Normal Force and Center of Pressure for the Hermes A-1E2 Wingless Configuration. Rep. No. R52A0508, Project HERMES, General Electric, Apr. 1952.

64. Robinson, Ross B., and Driver, Cornelius: Aerodynamic Characteristics at Supersonic Speeds of a Series of Wing-Body Combinations Having Cambered Wings With an Aspect Ratio of 3.5 and a Taper Ratio of 0.2 - Effects of Sweep Angle and Thickness Ratio on the Aerodynamic Characteristics in Pitch at M = 1.60. NACA RM L51K16a, 1952.

65. Nielsen, Jack N., Katzen, Elliott D., and Tang, Kenneth K.: Lift and Pitching-Moment Interference Between a Pointed Cylindrical Body and Triangular Wings of Various Aspect Ratios at Mach Numbers of 1.50 and 2.02. NACA TN 3745, 1956. (Supersedes NACA RM A50F06.)

66. Nielsen, Jack N., and Kaattari, George E.: Method for Estimating Lift Interference of Wing-Body Combinations at Supersonic Speeds. NACA RM A51J04, 1951.

67. Tucker, Warren A.: A Method for Estimating the Components of Lift of Wing-Body Combinations at Supersonic Speeds. NACA RM L52D22, 1952.

68. Nielsen, Jack N., Kaattari, George E., and Anastasio, Robert F.: A Method for Calculating the Lift and Center of Pressure of Wing-Body-Tail Combinations at Subsonic, Transonic, and Supersonic Speeds. NACA RM A53G08, 1953.

69. Kaattari, George E., Nielsen, Jack N., and Pitts, William C.: Method for Estimating Pitching-Moment Interference of Wing-Body Combinations at Supersonic Speed. NACA RM A52B06, 1952.

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## BIBLIOGRAPHY

1. Letko, William, and Goodman, Alex: Preliminary Wind-Tunnel Investigation at Low Speed of Stability and Control Characteristics of Swept-Back Wings. NACA TN 1046, 1946.

2. DeYoung, John: Theoretical Additional Span Loading Characteristics of Wings With Arbitrary Sweep, Aspect Ratio, and Taper Ratio. NACA TN 1491, 1947.

3. Fisher, Lewis R.: Approximate Corrections for the Effects of Compressibility on the Subsonic Stability Derivatives of Swept Wings. NACA TN 1854, 1949.

4. Michael, William H., Jr.: Flow Studies in the Vicinity of a Modified Flat-Plate Rectangular Wing of Aspect Ratio 0.25. NACA TN 2790, 1952.

5. Sacks, Alvin H.: Aerodynamic Forces, Moments, and Stability Derivatives for Slender Bodies of General Cross Section. NACA TN 3283, 1954.

6. Summers, James L., and Page, William A.: Lift and Moment Characteristics at Subsonic Mach Numbers of Four 10-Percent-Thick Airfoil Sections of Varying Trailing-Edge Thicknesses. NACA RM A50J09, 1950.

7. Hopkins, Edward J.: A Semiempirical Method for Calculating the Pitching Moment of Bodies of Revolution at Low Mach Numbers. NACA RM A51C14, 1951.

8. Hopkins, Edward J., and Carel, Hubert C.: Experimental and Theoretical Study of the Effects of Body Size on the Aerodynamic Characteristics of an Aspect Ratio 3.0 Wing-Body Combination. NACA RM A51G24, 1951.

9. Smith, Donald W., Shibata, Harry H., and Selan, Ralph: Lift, Drag, and Pitching Moment of Low-Aspect-Ratio Wings at Subsonic and Supersonic Speeds. An Investigation at Large Reynolds Numbers of the Low-Speed Characteristics of Several Wing-Body Combinations. NACA RM A51K28, 1952.

10. Scher, Stanley H., and Bowman, James S., Jr.: Stability of Bodies of Revolution Having Fineness Ratios Smaller Than 1.0 and Having Rounded Fronts and Blunt Bases. NACA RM L52L08, 1953.

11. Kelly, Howard R.: The Subsonic Aerodynamic Characteristics of Several Spin-Stabilized Rocket Models. I. Static Coefficients. TM-375, U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Nov. 12, 1953.

[redacted]

12. Kelly, Howard R.: The Estimation of Normal-Force, Drag, and Pitching-Moment Coefficients for Blunt-Based Bodies of Revolution at Large Angles of Attack. Jour. Aero. Sci., vol. 21, no. 8, Aug. 1954, pp. 549-555, 565.

13. Jaeger, B. F., Luther, M. L., and Schroedter, G. M.: The Aerodynamic Characteristics at Supersonic Speeds of Blunt-Trailing-Edge Airfoils for the NOTS Small-Caliber Air-to-Air Folding-Fin Rocket. NAVORD Rep. 1287 (NOTS 357), U. S. Naval Ord. Test Station, Inyokern, Feb. 24, 1951.

14. Kelley, J. L.: Summary of Aerodynamics Data on Finned Projectiles. Vol. I. Rep. No. 522, Ballistic Res. Labs., Aberdeen Proving Ground, Jan. 29, 1945.

15. Kelley, J. L.: Summary of Aerodynamics Data on Finned Projectiles. Vol. II. Rep. No. 522, Ballistics Res. Labs., Aberdeen Proving Ground, Jan. 29, 1945.

16. Stone, Howard N.: Calculation of Aerodynamic Characteristics of Low-Aspect-Ratio Wing-Body Combinations at Subsonic Speeds. Rep. No. AF-743-A-5 (Contract No. AF 33(038)-17397), Cornell Aero. Lab., Inc., Dec. 1952.

17. Kuchemann, D., and Kettle, D. J.: The Effect of Endplates on Swept Wings. C.P. No. 104, British A.R.C., 1952.

18. Hills, R.: The Aerodynamics of Armaments, Turrets and External Stores. Part I - An Analysis of Wind Tunnel Data on the Stability of Bombs and Rockets. Tech. Note No. Aero 2255, British R.A.E., Aug. 1953.

19. Von Kármán, Th., and Burgers, J. M.: General Aerodynamic Theory - Perfect Fluids. Vol. II of Aerodynamic Theory, div. E, W. F. Durand, ed., Julius Springer (Berlin), 1935.

20. Polhamus, Edward C.: Summary of Results Obtained by Transonic-Bump Method on Effects of Plan Form and Thickness on Lift and Drag Characteristics of Wings at Transonic Speeds. NACA TN 3469, 1955. (Supersedes NACA RM L51H30.)

21. Osborne, Robert S., and Mugler, John P., Jr.: Aerodynamic Characteristics of a 45° Sweptback Wing-Fuselage Combination and the Fuselage Alone Obtained in the Langley 8-Foot Transonic Tunnel. NACA RM L52E14, 1952.

22. Allen, Edwin C.: Experimental Investigation of the Effects of Plan-Form Taper on the Aerodynamic Characteristics of Symmetrical Unswept Wings of Varying Aspect Ratio. NACA RM A53C19, 1953.

23. Burrows, Dale L., and Newman, Ernest E.: Wind-Tunnel Tests of a Model of a Wingless Fin-Controlled Missile To Obtain Static Stability and Control Characteristics Through a Range of Mach Numbers From 0.5 to 0.88. NACA RM L53J06, 1954.

24. Jaeger, B. F., Luther, M. L., and Schroedter, G. M.: The Aerodynamic Characteristics at High Subsonic Speeds of Blunt-Trailing-Edge Airfoils for the NOTS Small-Caliber Air-to-Air Folding-Fin Rocket. NAVORD Rep. 1289 (NOTS 359), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Feb. 24, 1951.

25. Spreiter, John R.: Aerodynamic Properties of Cruciform-Wing and Body Combinations at Subsonic, Transonic, and Supersonic Speeds. NACA TN 1897, 1949.

26. Stivers, Louis S., Jr., and Malick, Alexander W.: Wind-Tunnel Investigation at Mach Numbers From 0.50 to 1.29 of an All-Movable Triangular Wing of Aspect Ratio 4 Alone and With a Body. NACA RM A9L01, 1950.

27. Heitmeyer, John C.: Lift, Drag, and Pitching Moment of Low-Aspect-Ratio Wings at Subsonic and Supersonic Speeds - Body of Revolution. NACA RM A51H22, 1951.

28. Kurbjun, Max C.: Longitudinal Stability and Drag Characteristics of a Fin-Stabilized Body of Revolution With a Fineness Ratio of 12 as Measured by the Free-Fall Method. NACA RM L54E13, 1954.

29. Knechtel, Earl D., and Summers, James L.: Effects of Sweep and Taper Ratio on the Longitudinal Characteristics of an Aspect Ratio 3 Wing-Body Combination at Mach Numbers From 0.6 to 1.4. NACA RM A55A03, 1955.

30. Lyons, Eleanor Crow, ed.: Proceedings of the Bureau of Ordnance Symposium on Aeroballistics. NAVORD Rep. 1651 (Defense Res. Lab. Rep. No. 267), Nov. 16-17, 1950.

31. Hightower, Ronald C.: Lift, Drag, and Pitching Moment of Low-Aspect-Ratio Wings at Subsonic and Supersonic Speeds - Comparison of Three Wings of Aspect Ratio 2 of Rectangular, Sweptback, and Triangular Plan Form, Including Effects of Thickness Distribution. NACA RM A52L02, 1953.

32. Lomax, Harvard, and Byrd, Paul F.: Theoretical Aerodynamic Characteristics of a Family of Slender Wing-Tail-Body Combinations. NACA TN 2554, 1951.

33. Zalovcik, John A., and Adams, Richard E.: Preliminary Tests at Transonic Speeds of a Model of a Constant-Chord Wing With a Sweepback of 45° and an NACA $65_{(112)}$-210, a = 1.0 Airfoil Section. NACA ACR L5J16a, 1945. (Supersedes NACA MR L5A27b.)

34. Hemenover, Albert D., and Graham, Donald J.: Influence of Airfoil Trailing-Edge Angle and Trailing-Edge-Thickness Variation on the Effectiveness of a Plain Flap at High Subsonic Mach Numbers. NACA TN 3174, 1954.

35. Loving, Donald L., and Wornom, Dewey E.: Transonic Wind-Tunnel Investigation of the Interference Between a 45° Swept-Back Wing and a Systematic Series of Four Bodies. NACA RM L52J01, 1952.

36. Hallissy, Joseph M., and Bowman, Donald R.: Transonic Characteristics of a 45° Sweptback Wing-Fuselage Combination - Effect of Longitudinal Wing Position and Division of Wing and Fuselage Forces and Moments. NACA RM L52K04, 1953.

37. Estabrooks, Bruce B.: Transonic Wind-Tunnel Investigation of an Unswept Wing in Combination With a Systematic Series of Four Bodies. NACA RM L52K12a, 1953.

38. Kelly, Thomas C.: Transonic Wind-Tunnel Investigation of the Aerodynamic Characteristics of a 60° Triangular Wing in Combination With a Systematic Series of Three Bodies. NACA RM L52L22a, 1953.

39. Johnson, Harold S., and Hayes, William C.: Wind-Tunnel Investigation of the Effects of Various Dorsal-Fin and Vertical-Tail Configurations on the Directional Stability of a Streamlined Body of Transonic Speeds - Transonic-Bump Method. NACA RM L53B19, 1953.

40. Palmer, William E., and Burrows, Dale L.: A Transonic Wind-Tunnel Investigation of the Longitudinal Force and Moment Characteristics of Two Delta Wings and One Clipped-Tip Delta Wing of 4 Percent Thickness on a Slender Body. NACA RM L55A07a, 1955.

41. Roschke, E. J.: The Effect of Nose Truncation on the Aerodynamic Properties of 9-Caliber Long Army-Navy Spinner Rocket Models Near Sonic Velocity. Tech. Note No. 902, Ballistic Res. Labs., Aberdeen Proving Ground, May 1954.

42. Schmidt, L. E., and Murphy, C. H.: The Aerodynamic Properties of the 7-Caliber Army-Navy Spinner Rocket in Transonic Flight. Memo. Rep. No. 775, Ballistic Res. Labs., Aberdeen Proving Ground, Mar. 1954.

43. Osborne, Robert S.: A Transonic-Wing Investigation in the Langley 8-Foot High-Speed Tunnel at High Subsonic Mach Numbers and at a Mach Number of 1.2 - Wing-Fuselage Configuration Having a Wing of 45° Sweepback, Aspect Ratio 4, Taper Ratio 0.6, and NACA 65A006 Airfoil Section. NACA RM L50H08, 1950.

44. Heitmeyer, John C.: Effect of Nose Shape and Trailing-Edge Bluntness on the Aerodynamic Characteristics of an Unswept Wing of Aspect Ratio 3.1, Taper Ratio 0.4, and 3-Percent Thickness. NACA RM A54A04, 1954.

45. Wood, R. M.: Quick Methods for Estimating the Static Aerodynamic Coefficients of Shell. Memo. Rep. No. 854, Ballistic Res. Labs., Aberdeen Proving Ground, Nov. 1954.

46. Ferri, Antonio: Supersonic Flow Around Circular Cones at Angles of Attack. NACA Rep. 1045, 1951. (Supersedes NACA TN 2236.)

47. Harmon, Sidney M., and Jeffreys, Isabella: Theoretical Lift and Damping in Roll of Thin Wings With Arbitrary Sweep and Taper at Supersonic Speeds - Supersonic Leading and Trailing Edges. NACA TN 2114, 1950.

48. Moskowitz, Barry: Approximate Theory for Calculation of Lift of Bodies, Afterbodies, and Combinations of Bodies. NACA TN 2669, 1952.

49. Van Dyke, Milton: Aerodynamic Characteristics Including Scale Effect of Several Wings and Bodies Alone and in Combination at a Mach Number of 1.53. NACA RM A6K22, 1946.

50. Ellis, Macon C., Jr., and Hasel, Lowell E.: Preliminary Tests at Supersonic Speeds of Triangular and Swept-Back Wings. NACA RM L6L17, 1947.

51. Edwards, Sherman S.: Experimental Investigation at Supersonic Speeds of Side Scoops Employing Boundary-Layer Suction. NACA RM A9I29, 1949.

52. Allen, H. Julian, and Edward, Perkins W.: Characteristics of Flow Over Inclined Bodies of Revolution. NACA RM A50L07, 1951.

53. Luidens, Roger W., and Simon, Paul C.: Aerodynamic Characteristics of NACA RM-10 Missile in 8- by 6-Foot Supersonic Wind Tunnel at Mach Numbers from 1.49 to 1.98. III - Analysis of Force Distribution at Angle of Attack (Stabilizing Fins Removed). NACA RM E50I19, 1950.

54. Rainey, Robert W.: Langley 9-Inch Supersonic Tunnel Tests of Several Modifications of a Supersonic Missile Having Tandem Cruciform Lifting Surfaces - Three-Component Data Results of Models Having Ratios of Wing Span to Tail Span Equal to and Less Than 1 and Some Static Rolling-Moment Data. NACA RM L50G07, 1951.

55. Grigsby, Carl E.: Investigation at a Mach Number of 1.93 To Determine Lift, Drag, Pitching-Moment, and Average Downwash Characteristics for Several Missile Configurations Having Rectangular Wings and Tails of Various Spans. NACA RM L50I08, 1950.

56. Rainey, Robert W.: Langley 9-Inch Supersonic Tunnel Tests of Several Modifications of a Supersonic Missile Having Tandem Cruciform Lifting Surfaces - Three-Component Data Results of Models Having Ratios of Wing Span to Tail Span Less Than 1. NACA RM L50I29a, 1951.

57. Perkins, Edward W., Gowen, Forrest E., and Jorgensen, Leland H.: Aerodynamic Characteristics of the NACA RM-10 Research Missile in the Ames 1- by 3-Foot Supersonic Wind Tunnel No. 2 - Pressure and Force Measurements at Mach Numbers of 1.52 and 1.98. NACA RM A51G13, 1951.

58. Cohen, Robert J.: Aerodynamic Characteristics of Four Bodies of Revolution Showing Some Effects of Afterbody Shape and Fineness Ratio at Free-Stream Mach Numbers From 1.50 to 1.99. NACA RM E51C06, 1951.

59. Jack, John R., and Burgess, Warren C.: Aerodynamics of Slender Bodies at Mach Number of 3.12 and Reynolds Numbers From $2 \times 10^6$ to $15 \times 10^6$. I - Body of Revolution With Near-Parabolic Forebody and Cylindrical Afterbody. NACA RM E51H13, 1951.

60. Grigsby, Carl E.: Tests at Mach Number 1.62 of a Series of Missile Configurations Having Tandem Cruciform Lifting Surfaces. NACA RM L51J15, 1952.

61. Jack, John R., and Gould, Lawrence I.: Aerodynamics of Slender Bodies at Mach Number of 3.12 and Reynolds Numbers From $2 \times 10^6$ to $15 \times 10^6$. II. Aerodynamic Load Distributions of Series of Five Bodies Having Conical Noses and Cylindrical Afterbodies. NACA RM E52C10, 1952.

62. Ulmann, Edward F., and Dunning, Robert W.: Aerodynamic Characteristics of Two Delta Wings at Mach Number 4.04 and Correlations of Lift and Minimum-Drag Data for Delta Wings at Mach Numbers From 1.62 to 6.9. NACA RM L52K19, 1952.

63. Jack, John R., and Moskowitz, Barry: Aerodynamics of Slender Bodies at Mach number of 3.12 and Reynolds Numbers From $2 \times 10^6$ to $15 \times 10^6$. IV - Aerodynamic Characteristics of Series of Four Bodies Having Near-Parabolic Noses and Cylindrical Afterbodies. NACA RM E53J27, 1954.

64. Hamilton, Clyde V., Driver, Cornelius, and Sevier, John R., Jr.: Wind-Tunnel Investigation of a Ram-Jet Missile Model Having a Wing and Canard Surfaces of Delta Plan Form With 70° Swept Leading Edges. Force and Moment Characteristics of Various Combinations of Components at a Mach Number of 1.6. NACA RM L53A14, 1953.

65. Goin, Kennith L., and Westrick, Gertrude C.: Effects of Trailing-Edge Bluntness on the Lift, Drag, and Pitching-Moment Characteristics of Unswept, 45° Swept, and 45° Delta Wings at Mach Numbers of 1.41, 1.62, and 1.96. NACA RM L53D13, 1953.

66. Rainey, Robert W.: Effect of Variations in Reynolds Number on the Aerodynamic Characteristics of Three Bomb or Store Shapes at a Mach Number of 1.62 With and Without Fins. NACA RM L53D27, 1953.

67. Cooper, Morton, and Sevier, John R., Jr.: Effects of a Series of Inboard Plan-Form Modifications on the Longitudinal Characteristics of Two 47° Sweptback Wings of Aspect Ratio 3.5, Taper Ratio 0.2, and Different Thickness Distributions at Mach Numbers of 1.61 and 2.01. NACA RM L53E07a, 1953.

68. Grigsby, Carl E., and Ogburn, Edmund L.: Investigation of Reynolds Number Effects for a Series of Cone-Cylinder Bodies at Mach Numbers of 1.62, 1.93, and 2.41. NACA RM L53H21, 1953.

69. Spearman, M. Leroy: Aerodynamic Characteristics in Pitch of a Series of Cruciform-Wing Missiles With Canard Controls at a Mach Number of 2.01. NACA RM L53I14, 1953.

70. Robins, A. Warner: Preliminary Investigation of the Effects of Several Seeker-Nose Configurations on the Longitudinal Characteristics of a Canard-Type Missile at a Mach Number of 1.60. NACA RM L53I18, 1953.

71. Ulmann, Edward F., and Bertram, Mitchel H.: Aerodynamic Characteristics of Low-Aspect-Ratio Wings at High Supersonic Mach Numbers. NACA RM L53I23, 1953.

72. Sevier, John R., Jr.: Effects of a Series of Inboard Plan-Form Modifications on the Longitudinal Characteristics of Two Unswept Wings of Aspect Ratio 3.5, Taper Ratio 0.2, and Different Thickness Distributions at Mach Numbers of 1.61 and 2.01. NACA RM L53K11, 1954.

73. Neice, Stanford E.: Experimental Investigation of the Aerodynamic Characteristics of a Ballistic-Type Missile. NACA RM A54C04, 1954.

74. Canning, Thomas N.: Investigation of the Lift, Center of Pressure, and Drag of a Projectile at a Mach Number of 8.6 and a Reynolds Number of 17 Million. NACA RM A54H23a, 1954.

75. Penland, Jim A.: Aerodynamic Characteristics of a Circular Cylinder at Mach Number 6.86 and Angles of Attack Up to 90°. NACA TN 3861, 1957. (Supersedes NACA RM L54A14, 1954.)

76. Spearman, M. Leroy, and Robinson, Ross B.: Aerodynamic Characteristics of a Cruciform-Wing Missile With Canard Control Surfaces and of Some Very Small Span Wing-Body Missiles at a Mach Number of 1.41. NACA RM L54B11, 1954.

77. Ulmann, Edward F., and Dunning, Robert W.: Normal Force, Center of Pressure, and Zero-Lift Drag of Several Ballistic-Type Missiles at Mach Number 4.05. NACA RM L54D30a, 1954.

78. Spearman, M. Leroy, and Robinson, Ross B.: Aerodynamic Characteristics at a Mach Number of 2.01 of Two Cruciform Missile Configurations Having 70° Delta Wings With Length-Diameter Ratios of 14.8 and 17.7 With Several Canard Controls. NACA RM L54G20, 1954.

79. Gillespie, Warren, Jr.: Free-Flight Determination of Force and Stability Characteristics of an Inclined Body of Fineness Ratio 16.9 at a Mach Number of 1.74. NACA RM L54G28a, 1954.

80. Coletti, Donald E.: Investigation of Interference Lift, Drag, and Pitching Moment of a Series of Triangular Wing and Body Combinations at a Mach Number of 1.62. NACA RM L55B25, 1955.

81. Carlson, Harry W., and Gapcynski, John P.: An Experimental Investigation at a Mach Number of 2.01 of the Effects of Body Cross-Section Shape on the Aerodynamic Characteristics of Bodies and Wing-Body Combinations. NACA RM L55E23, 1955.

82. Anon.: Aeroballistic Research Investigation of a Rocket Model With Several Swept-Fin Tail Configurations at a Mach Number of 2.87 Conducted in the NOL 40 × 40 cm Supersonic Wind Tunnel No. 1. Memo. 10109, U. S. Naval Ord. Lab. (White Oak, Md.), Oct. 11, 1949.

83. DeMeritte, Fred J., and Darling, J. A.: Aeroballistic Research Investigation of Rectangular Fin Models at Mach Number 4.38 and 2.92. Memo. 10133, U. S. Naval Ord. Lab. (White Oak, Md.), June 2, 1950.

84. Brown, C. S.: Results and Projected Planning of a Study of the Aerodynamic Characteristics of Long Bodies of Revolution, and Fin-Body Combinations at Supersonic Velocities. Tech. Memo. RRB-68, U. S. Naval Ord. Test Station, Res. Dept., Ballistics Div., Mar. 15, 1950.

85. Luther, M. L.: The Supersonic Lift and Centers of Pressure of Rectangular Fin Assemblies in Combination With a Long Cylindrical Body. Tech. Memo. RRB-69, U. S. Naval Ord. Test Station, Res. Dept., Ballistics Div., Mar. 15, 1950.

86. Luther, M. L.: The Supersonic Lift and Centers of Pressure of Folding-Fin Assemblies in Combination With a Long Cylindrical Body. Tech. Memo. RRB-71, U. S. Naval Ord. Test Station, Res. Dept., Ballistics Div., Mar. 15, 1950.

87. Delancey, L. M., and Jaeger, B. F.: Wind-Tunnel Tests at Mach Number 1.5 on Models of 5.0-Inch Spin and Fin-Spin Rockets. NAVORD Rep. 1175 (NOTS 231), U. S. Naval Ord. Test Station (Inyokern, Calif.), Aug. 15, 1949.

88. Luther, M. L.: The Supersonic Lift and Centers of Pressure of Rectangular Fin Assemblies in Combination With a Long, Cylindrical Body. NAVORD Rep. 1249 (NOTS 312), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Aug. 23, 1950.

89. Jaeger, B. F., Knemeyer, F. H., and Schroedter, G. M.: Wind-Tunnel Tests at Mach Numbers 1.5 and 2.0 on Models of a 2.75-Inch Folding-Fin Rocket. NAVORD Rep. 1284 (NOTS 354), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Feb. 27, 1951.

90. Luther, M. L., Jaeger, B. F., and Schroedter, G. M.: The Lift and Center of Pressure at Supersonic Speeds of Blunt-Trailing-Edge Airfoils With and Without Sweepback. NAVORD Rep. 1288 (NOTS 358), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Feb. 24, 1951.

91. Luther, Marvin L., and Schroedter, G. M.: The Supersonic Lift and Center of Pressure of Swept-Leading-Edge Fin Assemblies in Combination With a Long Cylindrical Body. NAVORD Rep. 1315 (NOTS 386), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), May 14, 1951.

92. Luther, Marvin L., and Schroedter, G. M.: The Supersonic Lift on Blunt- and Sharp-Trailing-Edge Folding Fins in Combination With a Long Body. NAVORD Rep. 1317 (NOTS 391), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), June 4, 1951.

93. Luther, M. L., and Jaeger, B. F.: Effects of Varying the Numbers of Fins on Fin-Stabilized Supersonic Rockets. NAVORD Rep. 1900 (NOTS 424), U. S. Naval Ord. Test Station, Inyokern (China Lake, Calif.), Aug. 9, 1951.

94. Anon.: The Effect of High Stability Noses on Finned Configurations. Tech. Note No. 707, Ballistic Res. Labs., Aberdeen Proving Ground, June 1952.

95. Murphy, C. H., and Schmidt, L. E.: The Effect of Length on the Aerodynamic Characteristics of Bodies of Revolution in Supersonic Flight. Rep. No. 876, Ballistic Res. Labs., Aberdeen Proving Ground, Aug. 1953.

96. Platou, A. S.: Body Nose Shapes for Obtaining High Static Stability. Memo. Rep. No. 592, Ballistic Res. Labs., Aberdeen Proving Ground, Feb. 1952.

97. Krieger, R. H., and Hughes, J. M.: Wind Tunnel Tests on British Finned Models With Varying Body and Fin Parameters. Memo. Rep. No. 768, Ballistic Res. Labs., Aberdeen Proving Ground, Mar. 1954.

98. Herrmann: Comparison of Stability Investigations on Projectiles With Various Fins. Trans. Rep. No. F-TS-1999-RE, Air Materiel Command, Wright Field, Feb. 1948.

99. Lapin, Ellis: Charts for the Computation of Lift and Drag of Finite Wings at Supersonic Speeds. Rep. No. SM-13480, Douglas Aircraft Co., Inc., Oct. 14, 1949.

100. Lagerstrom, P. A., and Graham, M. E.: Aerodynamic Interference in Supersonic Missiles. Rep. No. SM-13743, Douglas Aircraft Co., Inc., July 1950.

101. Buquoi, T. W.: Presentation of Force and Moment Data From Wind Tunnel Tests of an 0.06 Scale Control Development Model for the 1810 Missile at Mach Numbers 1.97, 2.55, and 3.67. Rep. No. SM-14929 (Contract No. DA-30-069-ORD-1082), Douglas Aircraft Co., Inc., Apr. 12, 1954.

102. Buquoi, T. W.: Presentation of Force and Moment Data From a Wind Tunnel Test of an 0.0333 Scale Wing Planform Development Model for the 1810 Missile at Mach Numbers 1.61, 1.97, 2.54, and 2.80 (Phase I). Rep. No. SM-18410 (Contract No. DA-30-069-ORD-1082), Douglas Aircraft Co., Inc., Aug. 23, 1954.

103. Klima, O., Jr., and Williamson, B.: Normal Force and Center-of-Pressure Tests for Various Body Configurations With and Without Half-Delta Tail-Fins at Mach 1.28 to 5.0. Rep. No. R50A0507, Project HERMES, General Electric, June 1950.

104. Raymond, J. L., and March, N. U.: Data Report on Normal Force, Pitching Moment, and Center of Pressure of the Hermes A-3B (XSSM-A-16) Configuration for the Mach Range 1.28 to 3.93. Rep. No. R53A0507, Project HERMES (Contract No. DA-30-115-ORD-23), General Electric, Mar. 1953.

105. Stewart, Homer J., and Meghreblian, Robert V.: Body-Wing Interference in Supersonic Flow. Progress Rep. No. 4-99, Jet Propulsion Lab., C.I.T., June 2, 1949.

106. Ross, F. W., and Dorrance, W. H.: An Introduction to a Supersonic Body Developmental Study. Rep. No. UMM-40 (USAF Contract W33-038-ac-14222), Aero. Res. Center, Univ. of Michigan, Dec. 1949.

107. Dorrance, W. H.: A Supersonic Body Profile Developmental Study. Report No. 2 - First Order and Linearized Theories for Supersonic Flow Around Bodies of Revolution With Experiments at Mach Number 1.90. Rep. No. UMM-54 (USAF Contract W-33-038-ac-14222), Aero. Res. Center, Univ. of Michigan, June 1, 1950.

108. Kelly, A. H., and Ross, F. W.: A Supersonic Body Profile Developmental Study. Rep. No. 4 - Twenty Degree Cone-Cylinder - Nine Degree Flare, Twenty Degree Cone-Cylinder - Five Degree Flare, Twenty Degree Cone - Four Degree Convergence - Five Degree Flare at Mach Number 1.90. Rep. No. UMM-58 (USAF Contract W33-038-ac-14222), Aero. Res. Center, Univ. of Michigan, July 31, 1950.

109. Kelly, A. H.: A Supersonic Body Profile Developmental Study. Report No. 5 - Ogive-Cylinder - Four and One Half Degree Flare, Ogive-Cylinder - Three Degree Flare, Ogive-Cylinder - Boat-Tail at Mach 1.90. Rep. No. UMM-64 (USAF Contract W33-038-ac-14222), Willow Run Res. Center, Univ. of Michigan, Oct. 1950.

110. Rodgers, E. J.: A Supersonic Body Profile Developmental Study. Report No. 7 - Twenty Degree Cone-Cylinder - Five Degree Glare, Ellipsoid-Cylinder - Five Degree Flare at Mach Numbers 1.9, 2.8, and 3.8. Rep. No. UMM-112 (USAF Contract W33-038-ac-14222), Willow Run Res. Center, Univ. of Michigan, Oct. 1951.

TABLE I.- CLASSIFICATION OF INFORMATION CONTAINED IN REFERENCES AND BIBLIOGRAPHY

[T, theoretical; X, experimental]

| Wing | Body | Wing-body combination | Wing-body interference | Reference or bibliography number |
|---|---|---|---|---|
| Subsonic speeds | | | | |
| T | | | | Ref. 5 |
| X | | | | Ref. 13 |
| X | | | | Ref. 15 |
| T | | | | Ref. 17 |
| X | | | | Ref. 18 |
| | X | T,X | T,X | Ref. 46 |
| | X | X | | Ref. 52 |
| X | | | | Bib. 1 |
| T | | | | Bib. 2 |
| T | | | | Bib. 3 |
| T,X | | | | Bib. 4 |
| T | T | T | | Bib. 5 |
| X | | | | Bib. 6 |
| | T,X | | | Bib. 7 |
| T,X | T,X | T,X | T,X | Bib. 8 |
| | | X | | Bib. 9 |
| | T,X | | | Bib. 10 |
| | X | X | | Bib. 11 |
| | T,X | | | Bib. 12 |
| X | | X | | Bib. 13 |
| | X | X | | Bib. 14 |
| | X | X | | Bib. 15 |
| | | | T,X | Bib. 16 |
| T,X | | | | Bib. 17 |
| | X | X | | Bib. 18 |
| T,X | T,X | T,X | | Bib. 19 |
| Subsonic and transonic speeds | | | | |
| X | | | | Ref. 7 |
| T,X | | | | Bib. 20 |
| | X | X | | Bib. 21 |
| | | X | | Bib. 22 |
| | | X | | Bib. 23 |
| X | | | | Bib. 24 |
| Subsonic, transonic, and supersonic speeds | | | | |
| | | T,X | | Ref. 1 |
| | X | | | Ref. 2 |
| T,X | | T,X | | Ref. 9 |
| | | X | | Ref. 23 |
| | T,X | | | Ref. 37 |
| | | T,X | T,X | Ref. 68 |
| | | T | | Bib. 25 |
| X | | T,X | X | Bib. 26 |
| | X | | | Bib. 27 |
| | | T,X | | Bib. 28 |
| | | T,X | | Bib. 29 |
| T,X | T,X | T,X | T,X | Bib. 30 |

| Wing | Body | Wing-body combination | Wing-body interference | Reference or bibliography number |
|---|---|---|---|---|
| Subsonic and supersonic speeds | | | | |
| T,X | | | | Ref. 12 |
| | X | X | | Ref. 56 |
| | | X | | Bib. 31 |
| Transonic speeds | | | | |
| X | | | | Ref. 14 |
| X | | X | | Ref. 22 |
| T,X | | | | Ref. 24 |
| | T,X | | | Ref. 47 |
| | X | T,X | | Ref. 49 |
| | X | X | | Ref. 59 |
| | | T | | Bib. 32 |
| X | | | | Bib. 33 |
| X | | | | Bib. 34 |
| | X | X | | Bib. 35 |
| | | X | | Bib. 36 |
| | | X | X | Bib. 37 |
| | | X | | Bib. 38 |
| | X | X | | Bib. 39 |
| | | T,X | | Bib. 40 |
| | X | | | Bib. 41 |
| | X | | | Bib. 42 |
| Transonic and supersonic speeds | | | | |
| | | X | | Bib. 43 |
| | | X | | Bib. 44 |
| | X | | | Bib. 45 |
| Supersonic speeds | | | | |
| | T | | | Ref. 3 |
| | | T,X | T,X | Ref. 4 |
| T | | | | Ref. 6 |
| T,X | | | | Ref. 8 |
| T,X | | | | Ref. 10 |
| T | | | | Ref. 11 |
| T,X | | X | | Ref. 16 |
| T,X | | | | Ref. 19 |
| X | | | | Ref. 20 |
| T,X | | | | Ref. 21 |
| | T,X | | | Ref. 25 |
| | T,X | | | Ref. 26 |
| | T,X | | | Ref. 27 |
| | X | X | | Ref. 28 |
| | T,X | | | Ref. 29 |
| | T,X | T,X | | Ref. 30 |
| | T,X | | | Ref. 31 |
| | T,X | | | Ref. 32 |

TABLE I.- CLASSIFICATION OF INFORMATION CONTAINED IN REFERENCES AND BIBLIOGRAPHY - Concluded

[T, theoretical; X, experimental]

| Wing | Body | Wing-body combination | Wing-body interference | Reference or bibliography number | Wing | Body | Wing-body combination | Wing-body interference | Reference or bibliography number |
|---|---|---|---|---|---|---|---|---|---|
| Supersonic speeds - Continued | | | | | Supersonic speeds - Concluded | | | | |
| | X | | | Ref. 33 | | X | T,X | X | Bib. 64 |
| | X | X | | Ref. 34 | | | T,X | | Bib. 65 |
| | X | X | | Ref. 35 | | X | X | | Bib. 66 |
| | X | | | Ref. 36 | | | T,X | | Bib. 67 |
| | X | | | Ref. 38 | | X | | | Bib. 68 |
| | T,X | | | Ref. 39 | | T,X | T,X | | Bib. 69 |
| | T,X | | | Ref. 40 | | | X | | Bib. 70 |
| | T,X | T,X | | Ref. 41 | T,X | | T,X | | Bib. 71 |
| | T,X | T,X | | Ref. 42 | | | T,X | | Bib. 72 |
| | T,X | X | | Ref. 43 | | T,X | | | Bib. 73 |
| | T,X | | | Ref. 44 | | X | | | Bib. 74 |
| | X | X | | Ref. 45 | | T,X | | | Bib. 75 |
| | T,X | | | Ref. 48 | | X | X | | Bib. 76 |
| | X | X | | Ref. 50 | | | T,X | | Bib. 77 |
| | X | X | | Ref. 51 | | T,X | T,X | | Bib. 78 |
| | X | X | | Ref. 53 | | T,X | | | Bib. 79 |
| | X | | | Ref. 54 | X | X | X | T,X | Bib. 80 |
| | X | X | | Ref. 55 | | T,X | T,X | | Bib. 81 |
| | X | X | | Ref. 57 | | | X | | Bib. 82 |
| | X | X | | Ref. 58 | | | X | | Bib. 83 |
| | X | X | | Ref. 60 | | | T,X | | Bib. 84 |
| | X | X | | Ref. 61 | | | T,X | | Bib. 85 |
| | | X | | Ref. 62 | | | T | | Bib. 86 |
| | X | | | Ref. 63 | | X | X | | Bib. 87 |
| | X | X | | Ref. 64 | | | T,X | | Bib. 88 |
| T,X | T,X | T,X | T,X | Ref. 65 | | | X | | Bib. 89 |
| | | | T,X | Ref. 66 | T | | | | Bib. 90 |
| T | | T,X | T,X | Ref. 67 | | | T | | Bib. 91 |
| | | T,X | T,X | Ref. 69 | | | T | | Bib. 92 |
| | T,X | | | Bib. 46 | | X | X | | Bib. 93 |
| T | | | | Bib. 47 | | X | X | | Bib. 94 |
| | T | | T | Bib. 48 | | T,X | | | Bib. 95 |
| T,X | T,X | X | X | Bib. 49 | | X | | | Bib. 96 |
| T,X | | | | Bib. 50 | | X | X | | Bib. 97 |
| | T,X | | | Bib. 51 | | | X | | Bib. 98 |
| | T,X | | | Bib. 52 | T | | | | Bib. 99 |
| | T,X | | | Bib. 53 | | | T | T | Bib. 100 |
| | X | X | X | Bib. 54 | | | X | | Bib. 101 |
| | X | X | T | Bib. 55 | | | X | | Bib. 102 |
| | X | X | X | Bib. 56 | | X | X | | Bib. 103 |
| | T,X | T,X | | Bib. 57 | | | X | | Bib. 104 |
| | T,X | | | Bib. 58 | | | | T | Bib. 105 |
| | T,X | | | Bib. 59 | | T | T | | Bib. 106 |
| | | X | | Bib. 60 | | T,X | | | Bib. 107 |
| | | T,X | | Bib. 61 | | T,X | | | Bib. 108 |
| T,X | | | | Bib. 62 | | T,X | | | Bib. 109 |
| | T,X | | | Bib. 63 | | T,X | | | Bib. 110 |

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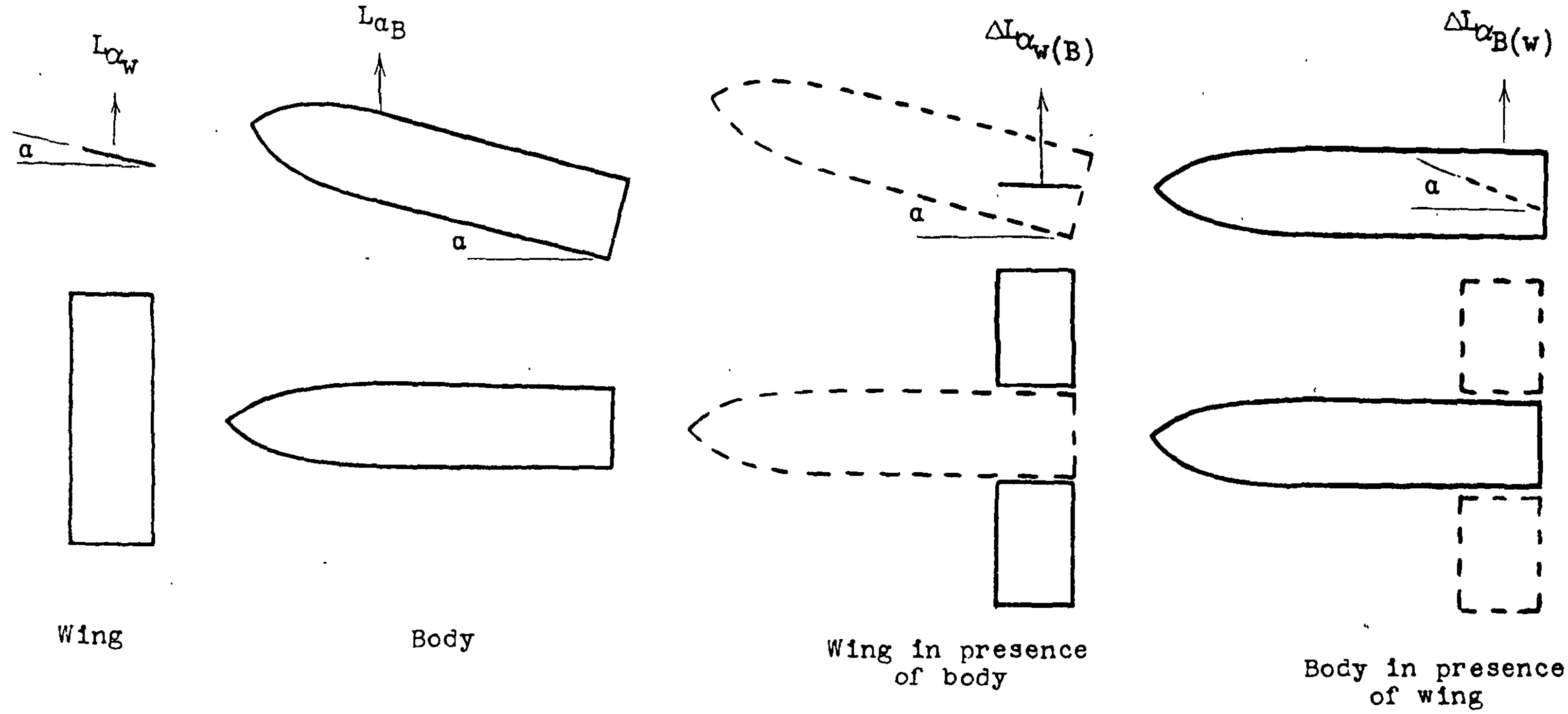



$$C_{L_\alpha} = \frac{L_{\alpha_{W(B)}} + L_{\alpha_{B(W)}}}{qS_W} \quad \text{where} \quad L_{\alpha_{W(B)}} = L_{\alpha_W} + \Delta L_{\alpha_{W(B)}} \quad \text{and}$$

$$L_{\alpha_{B(W)}} = L_{\alpha_B} + \Delta L_{\alpha_{B(W)}}$$

Figure 1.- Lift components on wing-body combinations.

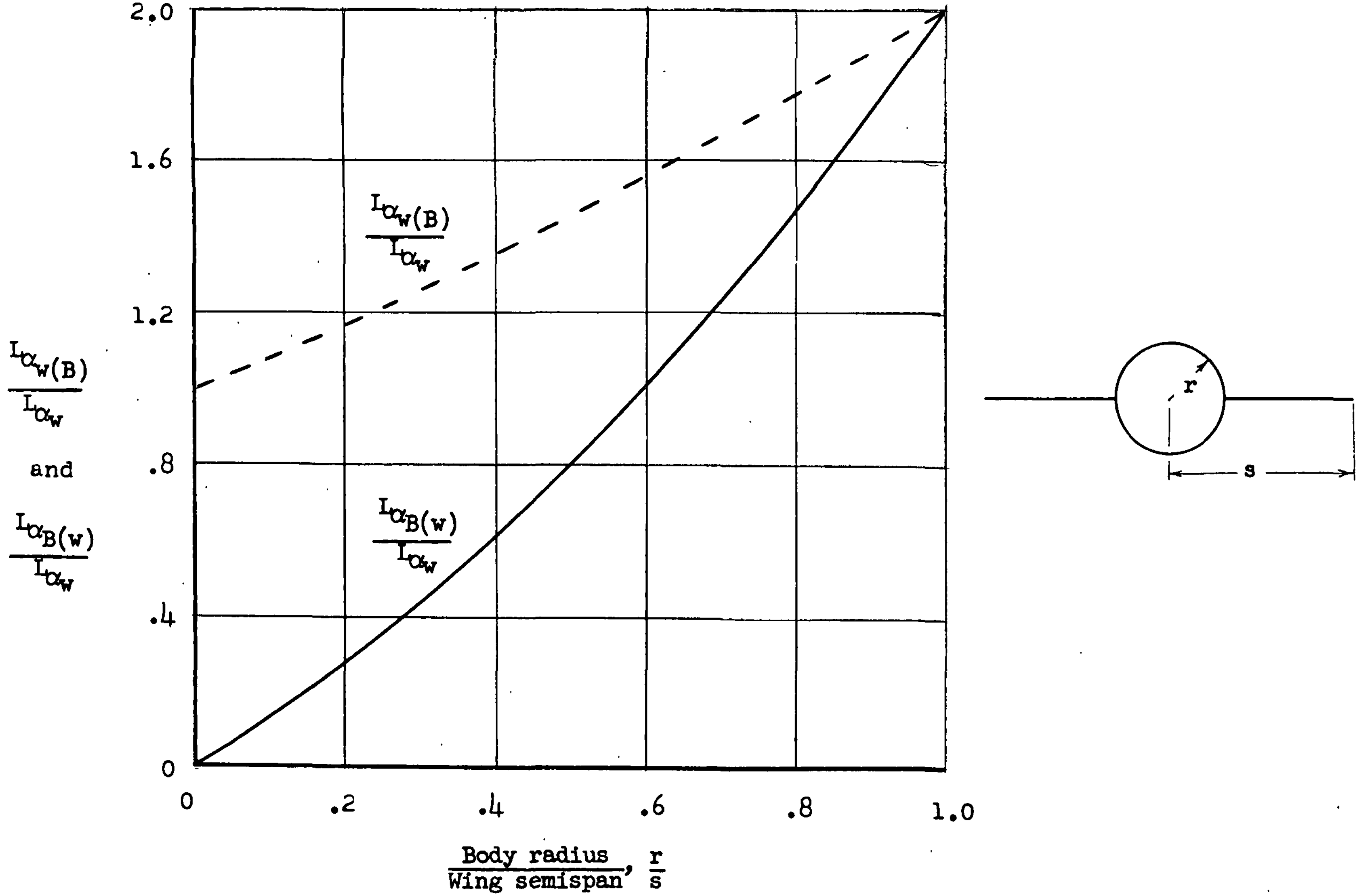



Figure 2.- Linear-theory values of wing-body lift interference. (See ref. 4.)

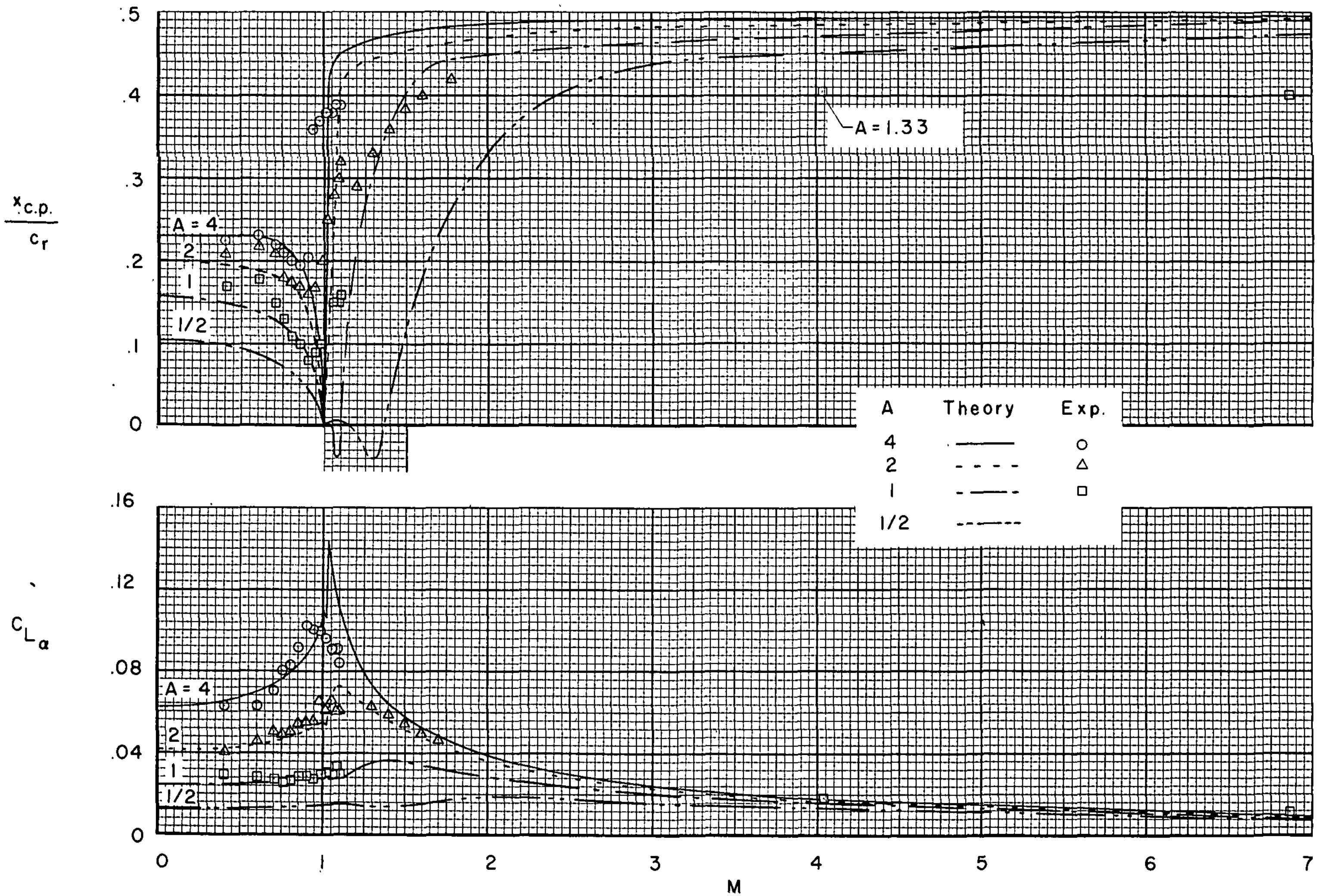



Figure 3.- Lift and center of pressure for rectangular wings. (Theory from refs. 5 and 6; experimental data from refs. 7 to 10.)

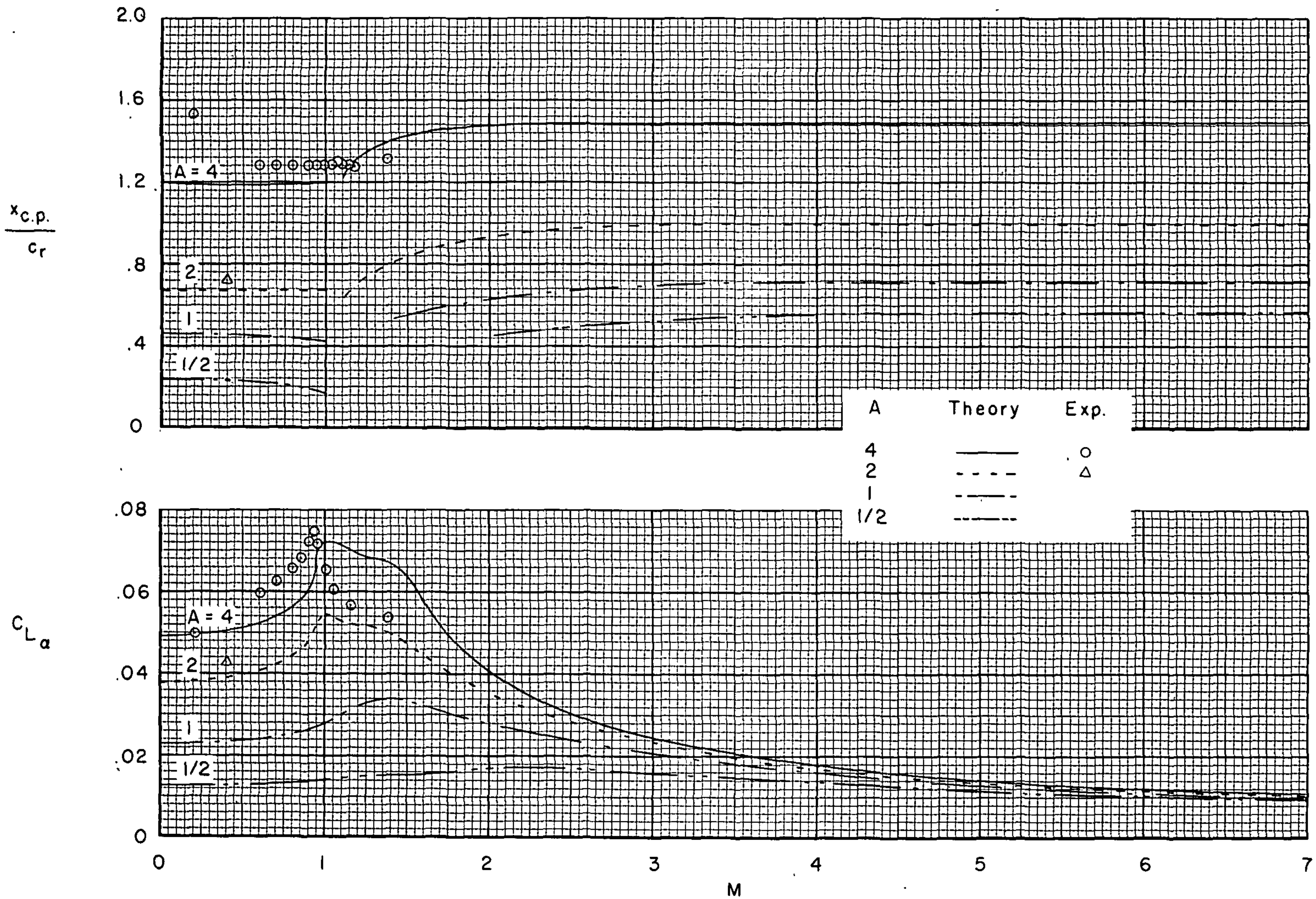



Figure 4.- Lift and center of pressure for untapered 45° sweptback wings. (Theory from refs. 6, 11, and 12; experimental data from refs. 13 to 16.)

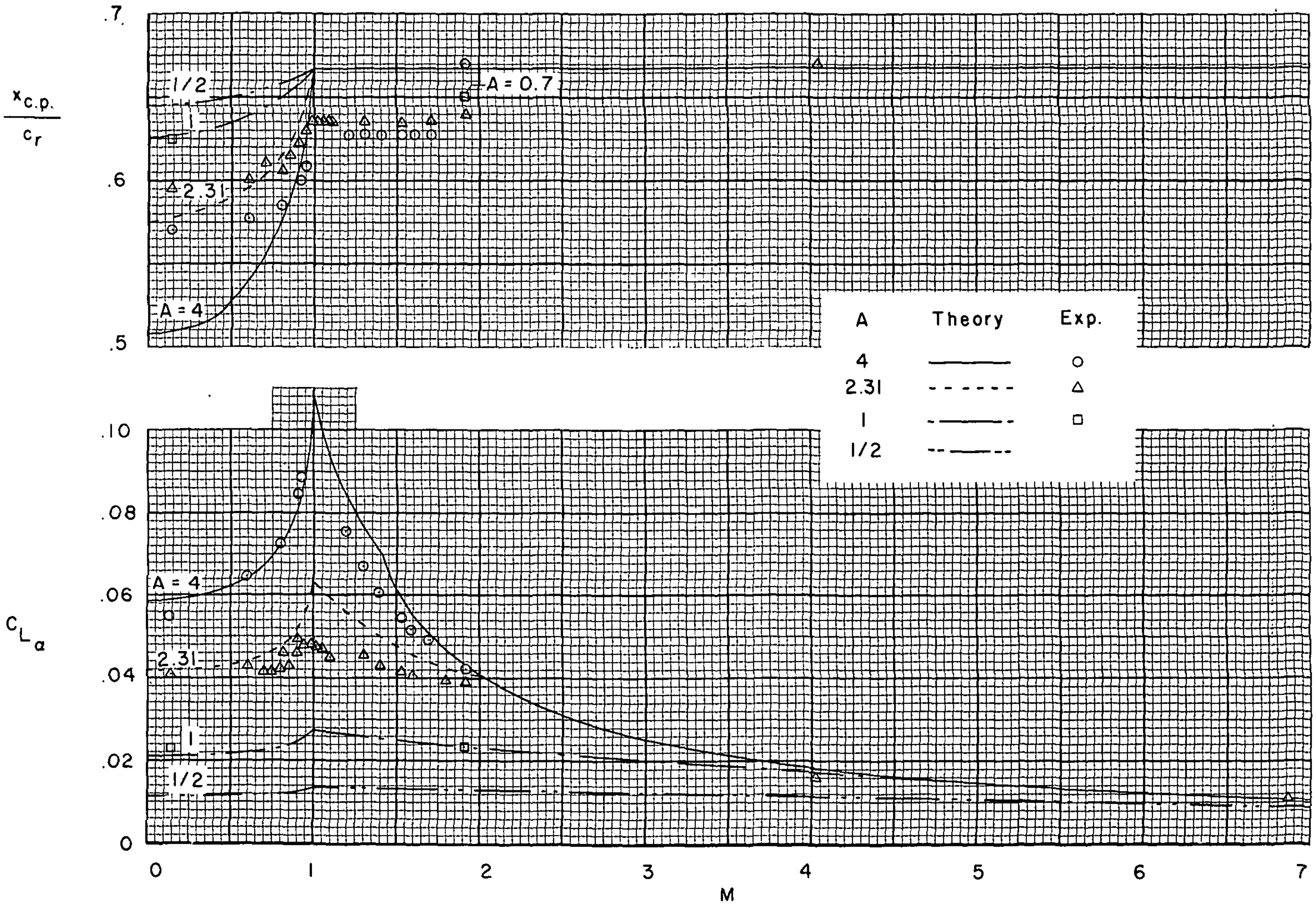



Figure 5.- Lift and center of pressure for delta wings. (Theory from refs. 5, 6, and 17; experimental data from refs. 9 and 18 to 21.)

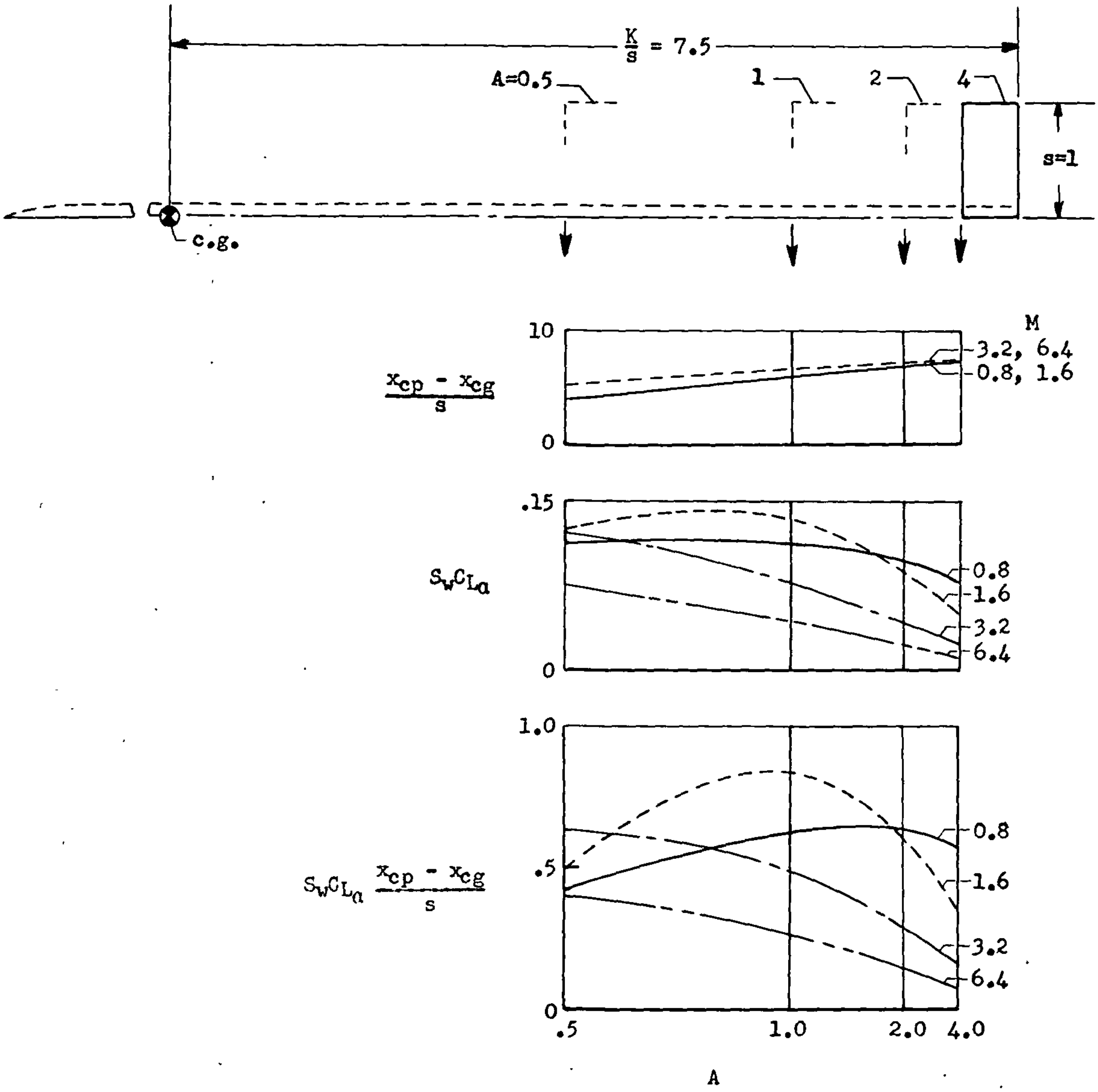



Figure 6.- Effect on static stability of adding wing chord when trailing edge of basic aspect-ratio-4 wing is at rear end of body. Rectangular wings.

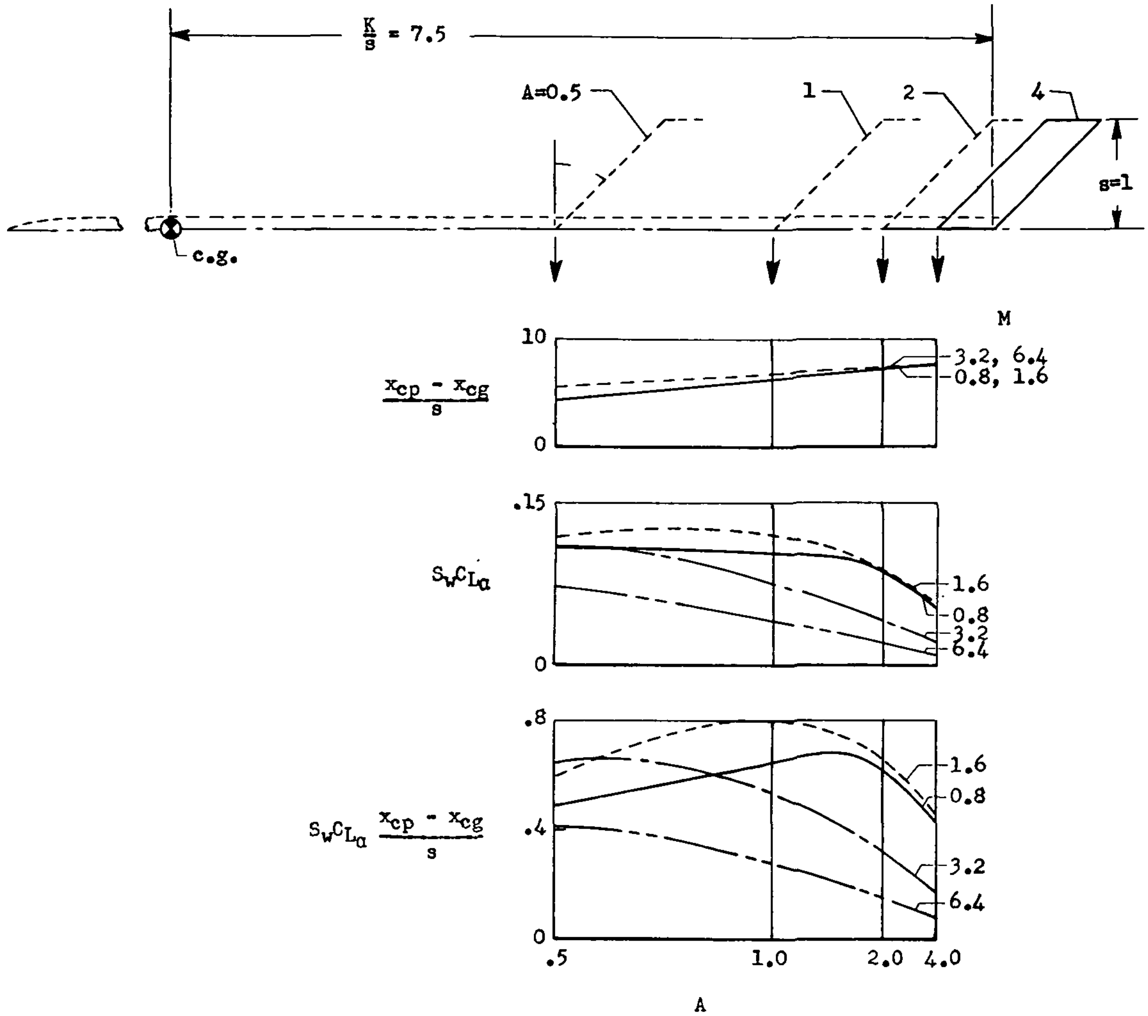



Figure 7.- Effect on static stability of adding wing chord when trailing edge of basic aspect-ratio-4 wing is at rear end of body. $45^{\circ}$ swept-back untapered wings.

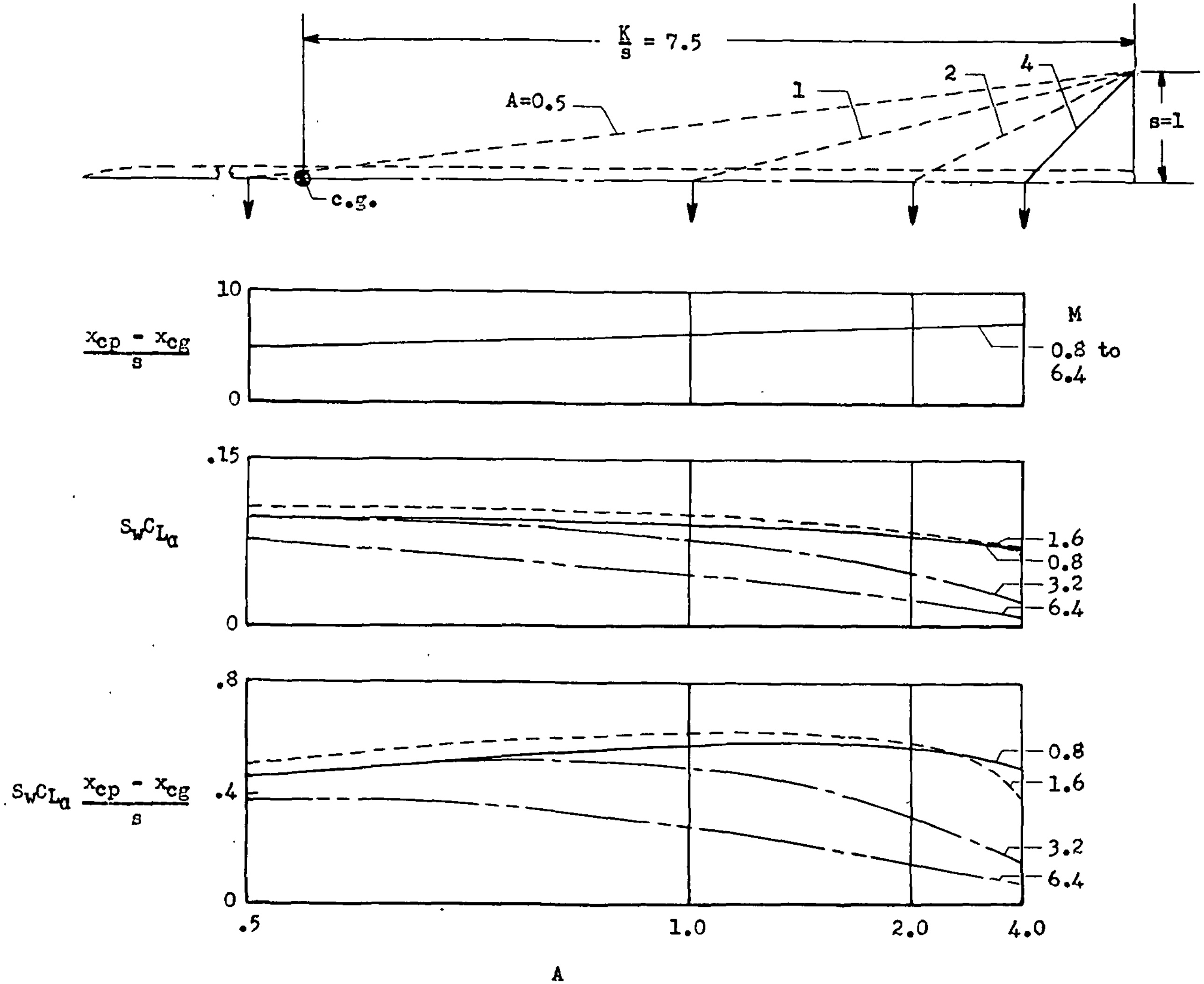



Figure 8.- Effect on static stability of adding wing chord when trailing edge of basic aspect-ratio-4 wing is at rear end of body. Delta wings.

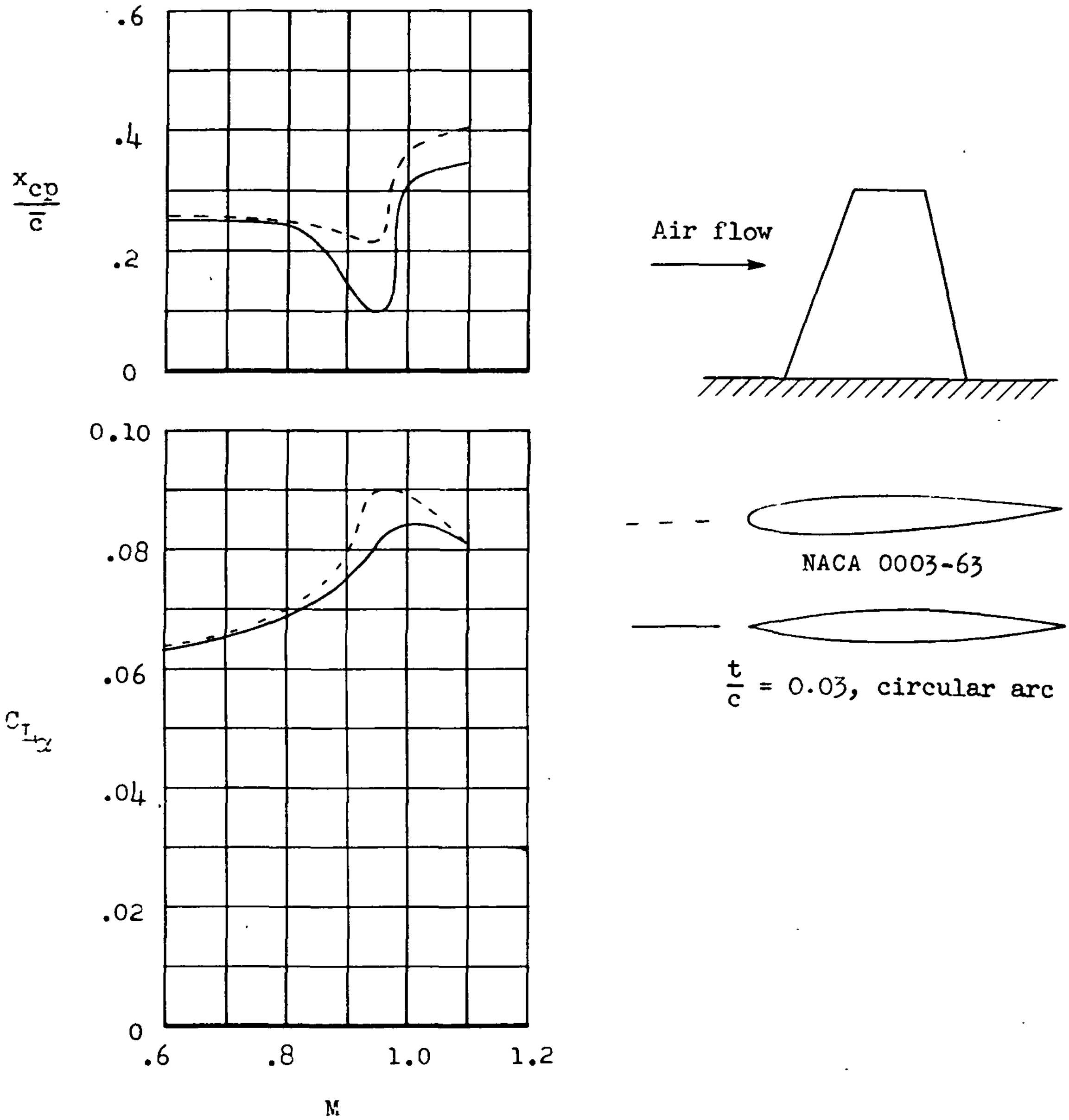



Figure 9.- Effect of airfoil section at transonic speeds. A = 3.1; taper ratio = 0.4; unswept wing alone. (See ref. 22.)

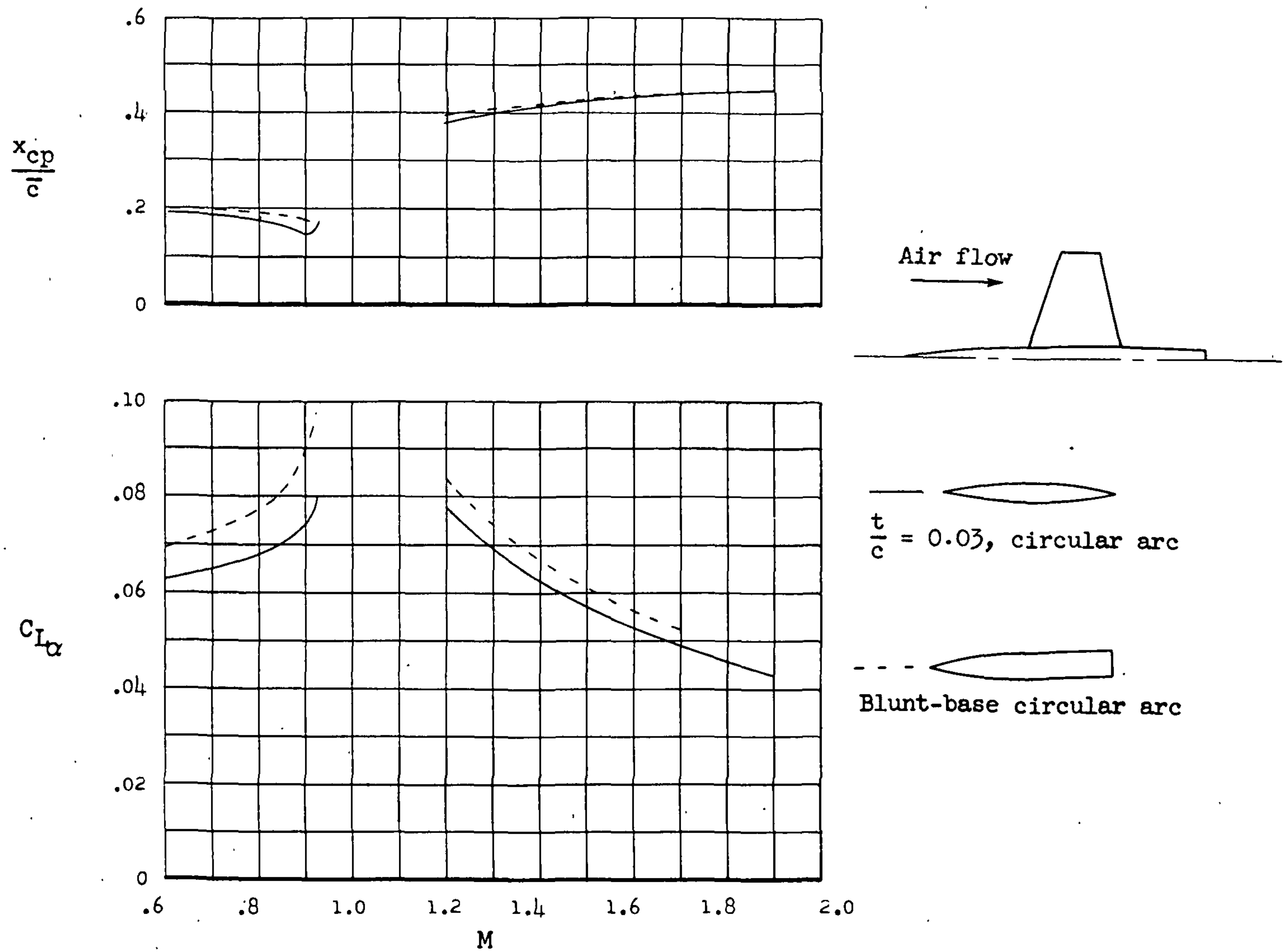



Figure 10.- Effect of airfoil section at subsonic and supersonic speeds. A = 3.1; taper ratio = 0.4; unswept-wing—body combination. (See ref. 23.)

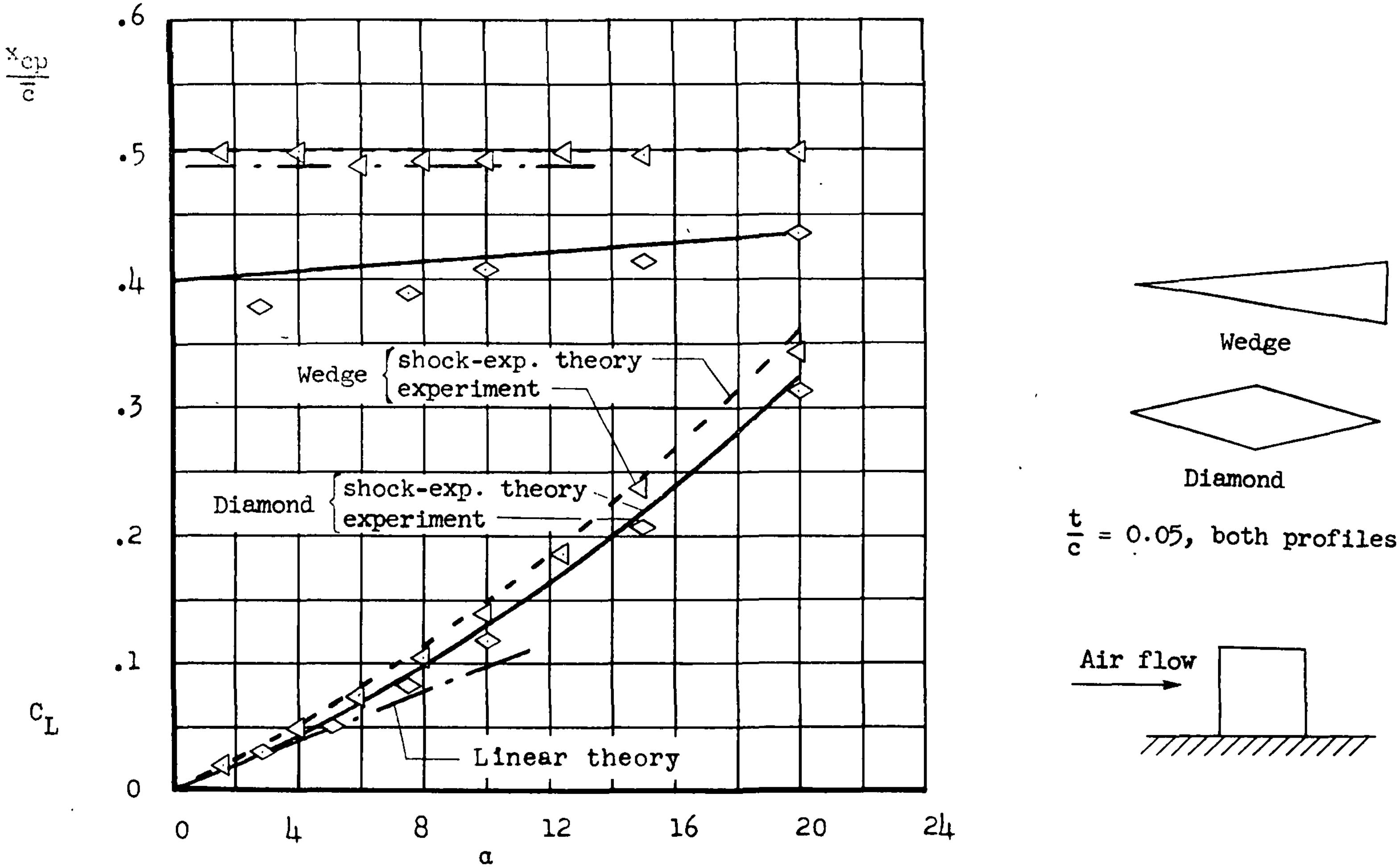



Figure 11.- Effect of airfoil section at M = 6.86. A = 1.0; wing alone. (See ref. 8.)

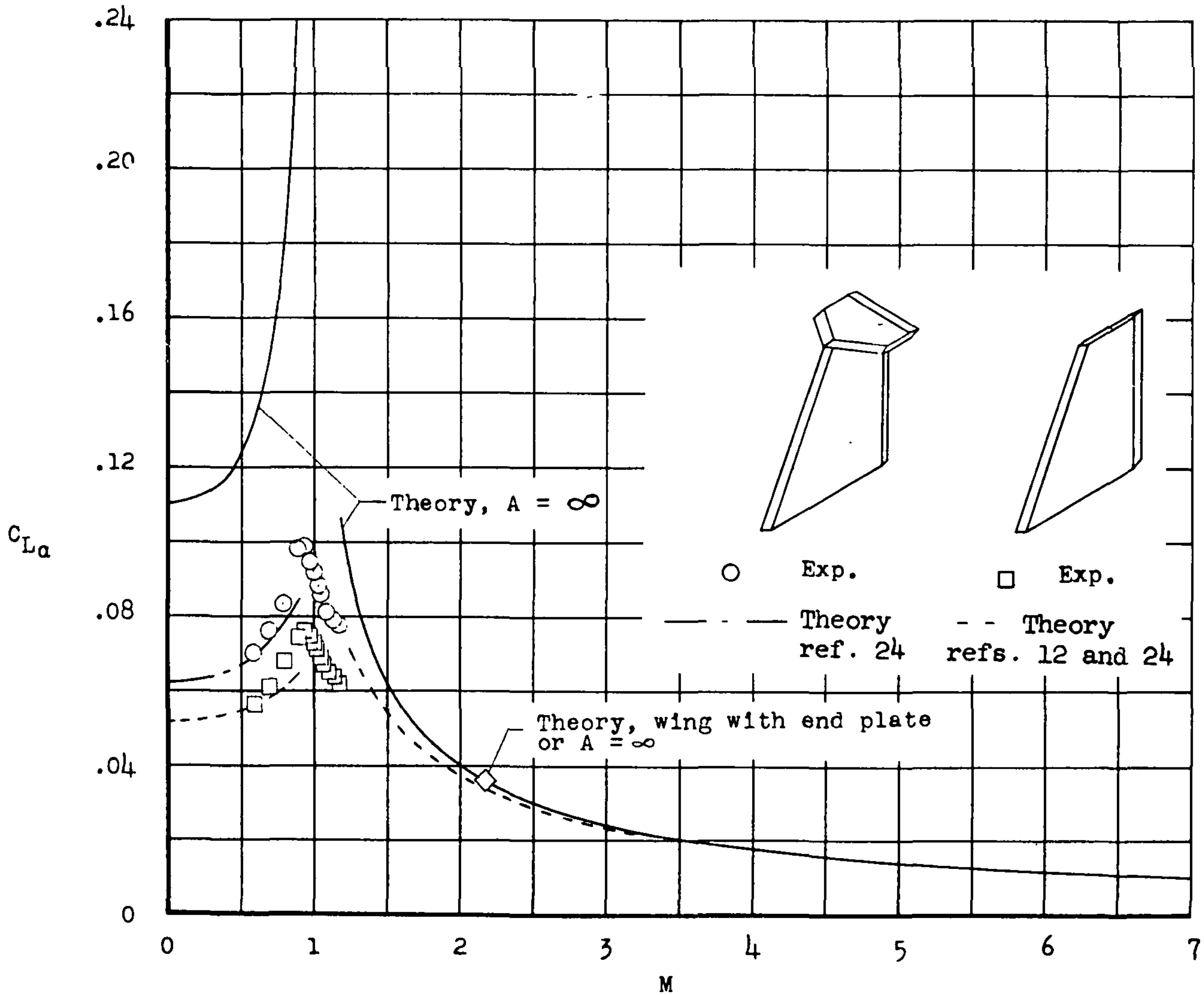
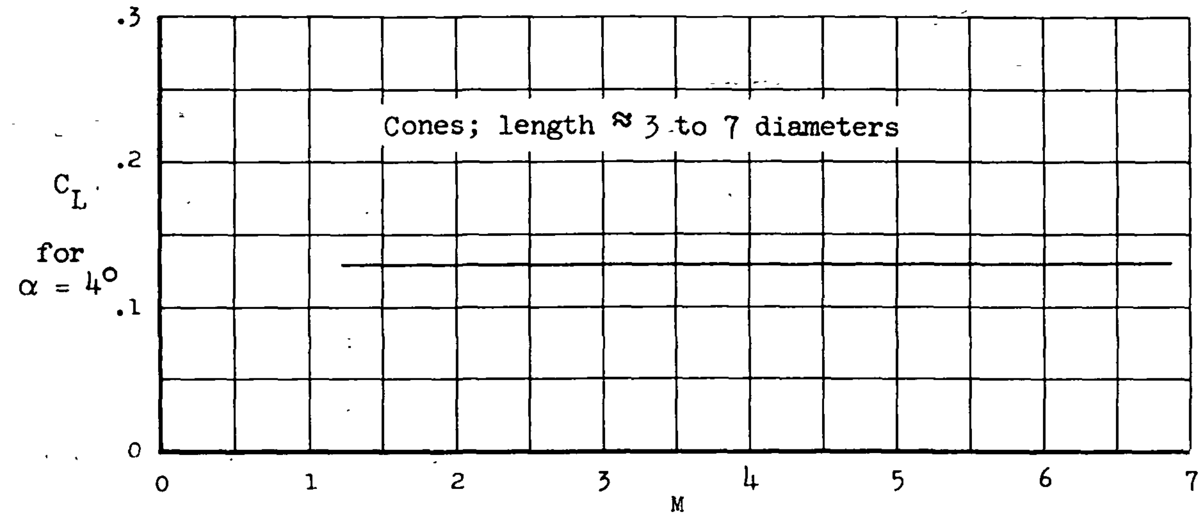



Figure 12.- Effect of end plate on lift. (Experimental data from ref. 24.)



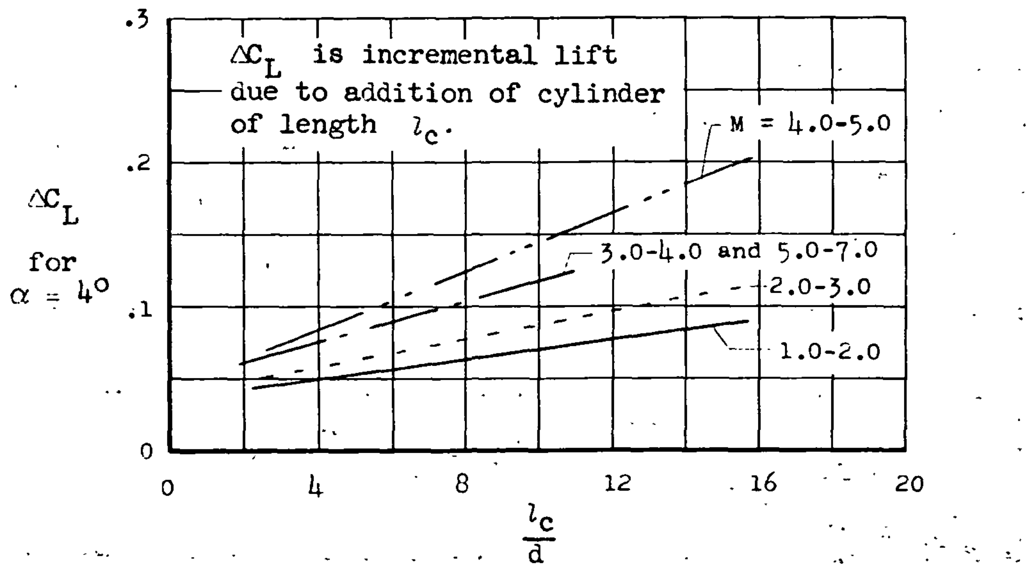
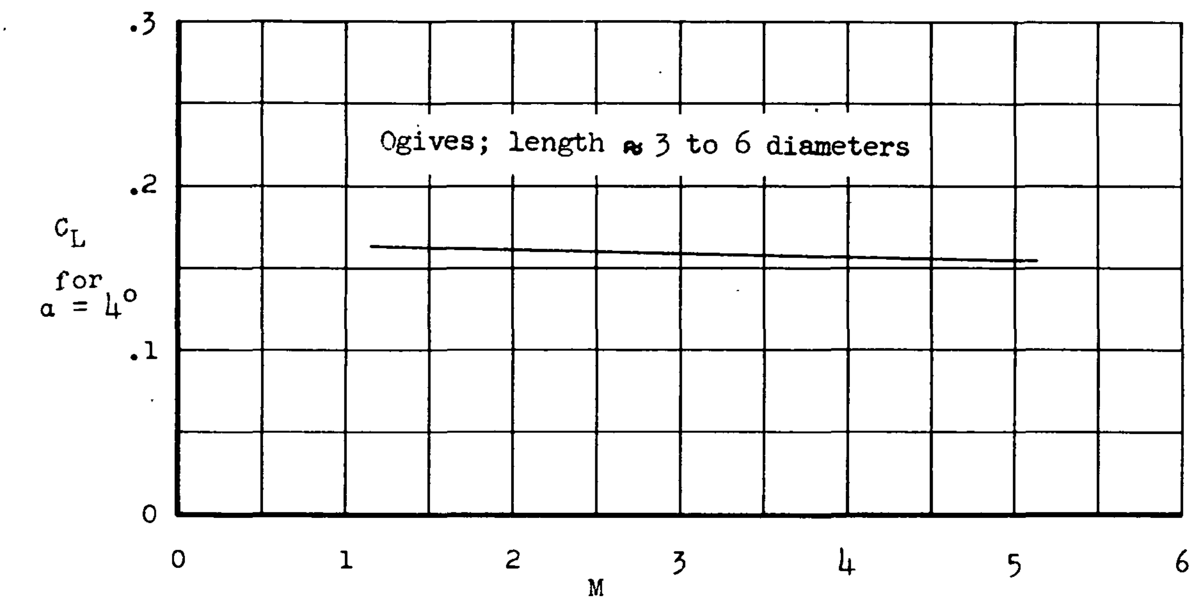




Figure 13.- Cone-cylinder lift. (Basic data for these curves may be found in refs. 25 to 39.)



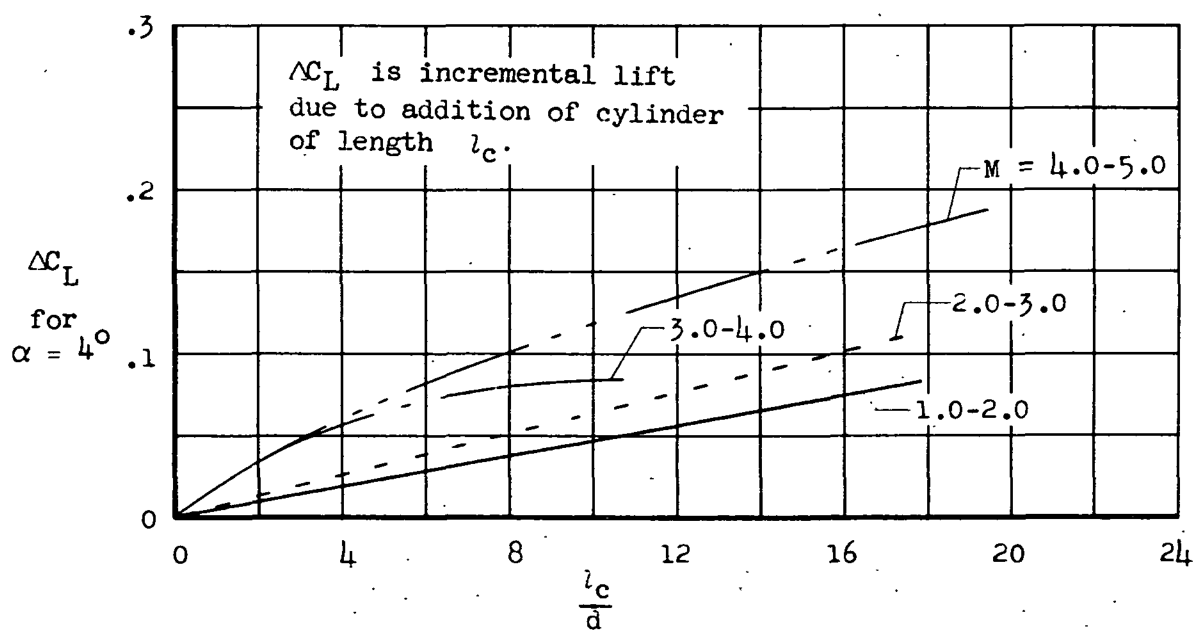




Figure 14.- Ogive-cylinder lift. (Basic data for these curves may be found in refs. 27, 31, 33, 34, 36, 38, 39, and 40 to 63.)

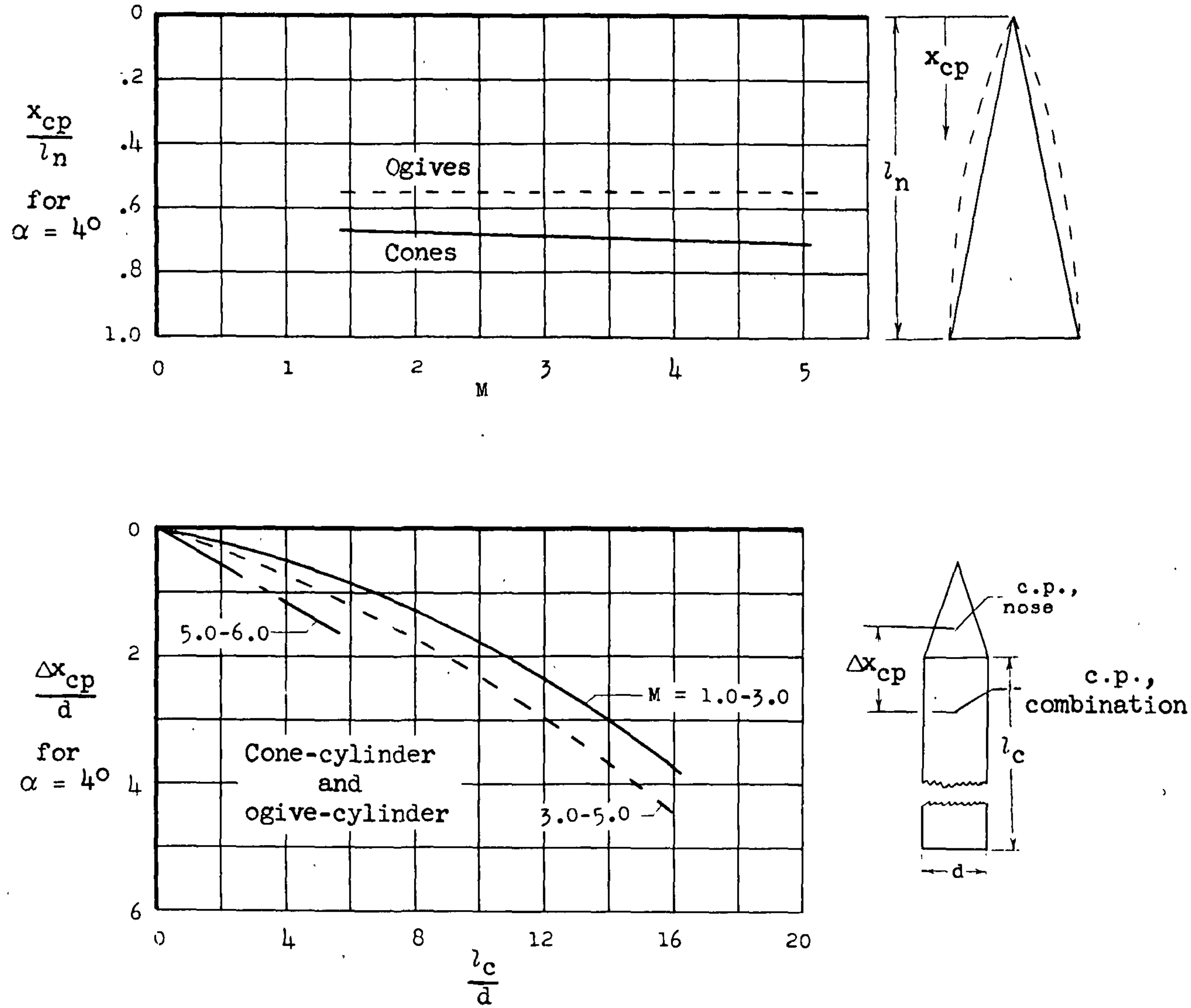



Figure 15.- Center of pressure for cone-cylinders and ogive-cylinders. (Basic data may be found in refs. 25 to 28, 30 to 39, 41 to 48, 50, 56, and 58 to 64.)

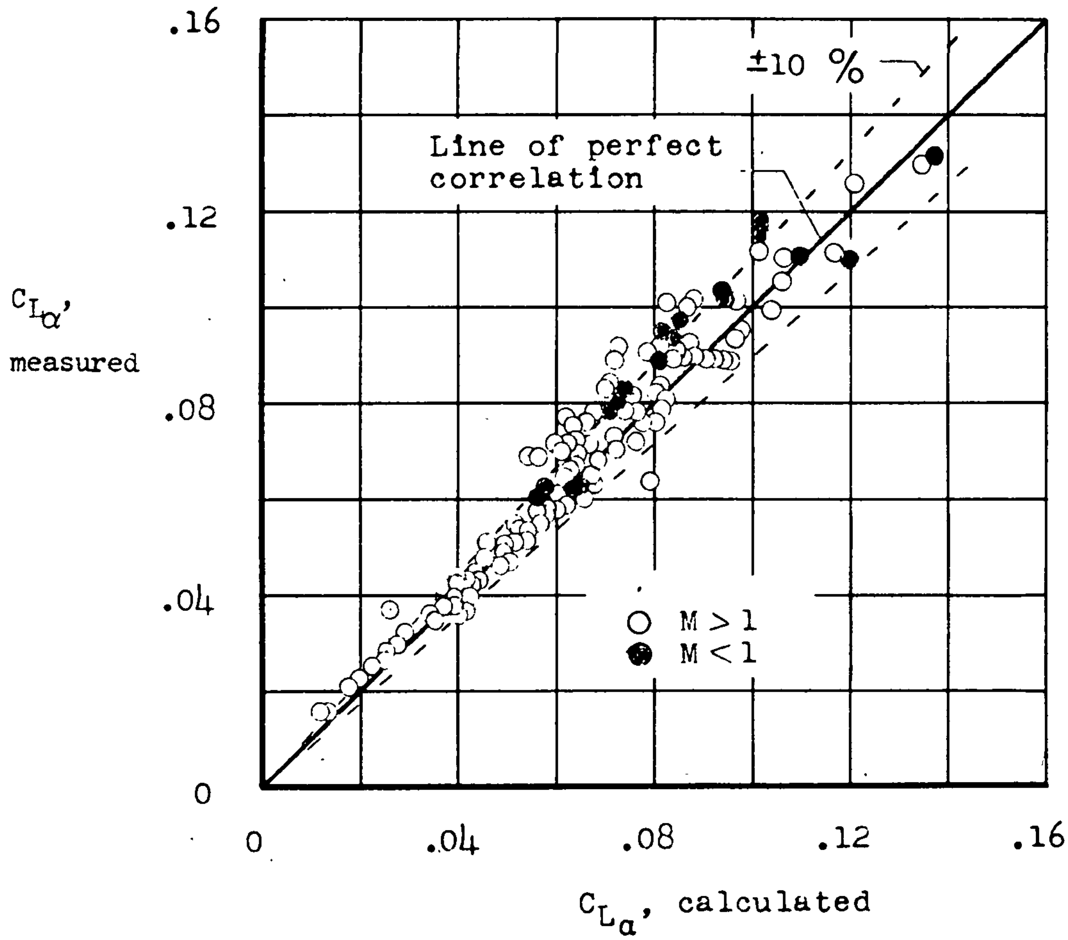



Figure 16.- Comparison between measured and calculated lift for complete wing-body combination. (See refs. 65 to 68.)

[redacted]

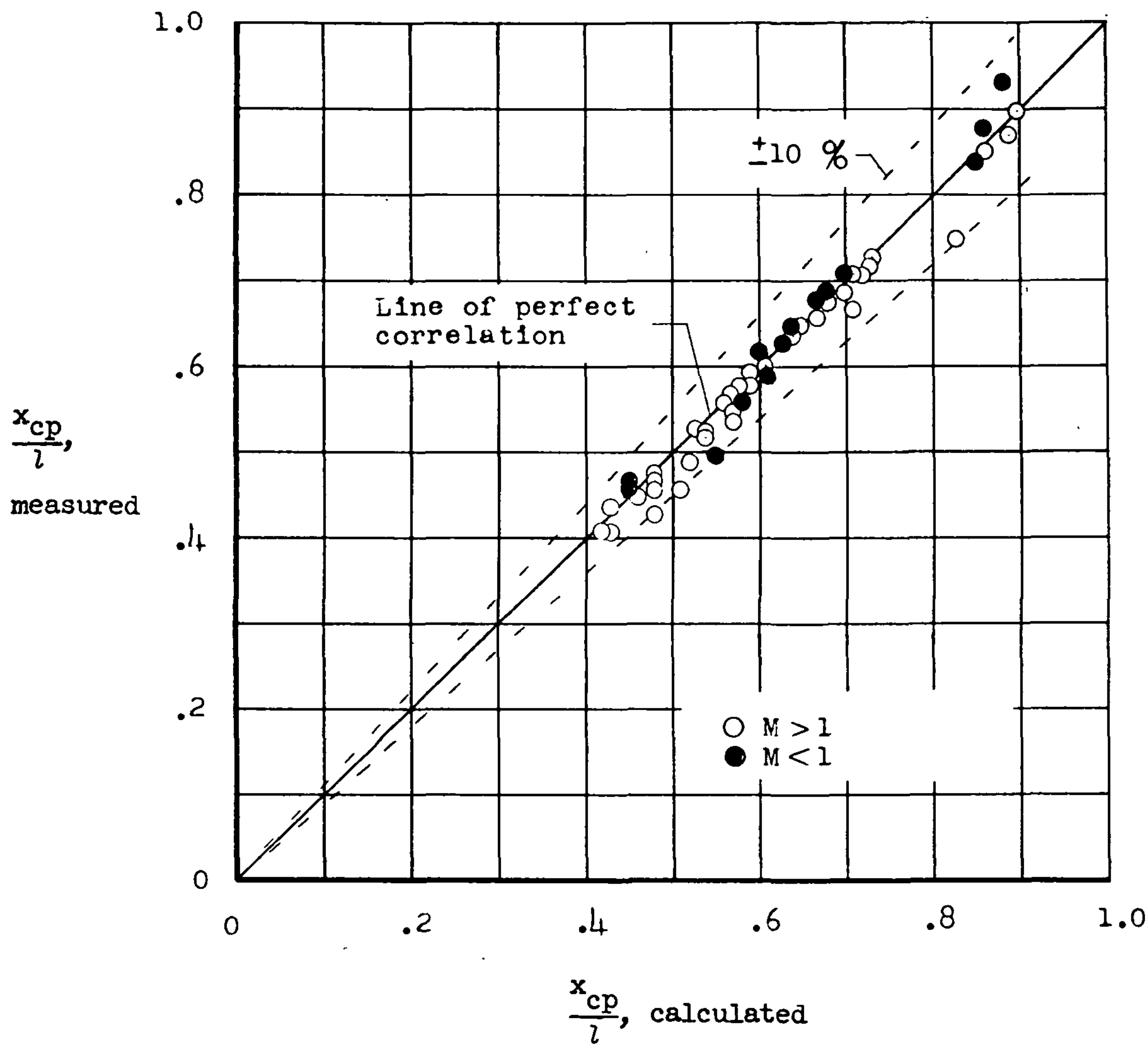



Figure 17.- Comparison between measured and calculated center of pressure for complete wing-body combination. (See refs. 4, 68, and 69.)

DECLASSIFIED